

COMPARATIVE OSTEOLOGY OF CERTAIN RAILS AND CRANES, AND THE SYSTEMATIC POSITIONS OF THE SUPERSUBORDERS GRUIFORMES AND RALLIFORMES

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NINE FIGURES

Owing to the existence of such peculiar birds as the Kagu (*Rhinocetus*); the finfoot (*Podica*); the *Ortygometra*; the sun bitttern (*Eurypyga*); the trumpeter (*Psophia*); the Madagascan genus *Mesites*, and the *Seriema* (*Dicholophus*), the exact limits of the rail and crane groups of birds still existing in nature have long been a mooted question with avian taxonomers; and far more light from anatomical sources is required before the true relationships of many of the groups and species just enumerated can be definitely determined.

Such classifications of the Class Aves as have appeared within comparatively recent times are much at variance with respect to opinions upon the groups to be discussed in the present article.

In order to demonstrate this, it is but necessary to present in brief several of the classifications of birds, which have been offered by writers of authority on the subject during the last century. For example, in the year 1813 the Academy of Sciences of Berlin, in its *Abhandlungen* (pp. 237-250), published a scheme of bird classification proposed by Blasius Merrem, entitled "*Tentamen Systematis Naturalis Avium*." That gifted writer distinguished his fourth group of birds as '*Aves palustres*,' and thus divided it:

4. Aves palustres:

A *Rusticolae*: (a) *Phalarides*—*Rallus*, *Fulica*, *Parra*; (b) *Limosugae*—*Nu-*
menius, *Scolopax*, *Tringa*, *Charadrius*, *Recurvirostra*

B *Grallae*: (a) *Erodii*—*Ardeae ungue intermedis serrato*, *Cancroma*; (b)
Pelargi—*Ciconia*, *Alycteria*, *Tantali quidam*, *Scopus*, *Platalea*; (c) *Gerani*—
Ardeae cristatae, *Grues*, *Psophia*

C *Otis*

For the time it was given, this classification is by no means lacking in merit, and there are taxonomers of the present day who may, with profit, still contemplate it.

Fourteen years later l'Herminier, in his "Recherches sur l'appareil sternal des oiseaux," published in the 'Actes' of the Linnean Society of Paris (T. 6, pp. 3-93), showed upon osteological grounds that the Rallidae and the true cranes (*Grus*) were affined; that neither family was especially related to the herons (*Ardeidae*), and so should be separated from them.

Passing to the classifications of many of the other early writers—always more or less conflicting in their views—we come to the famous scheme of Professor Huxley, so frequently quoted in previous papers of mine (P. Z. S., 1867). In his Order III (CARINATAE, Merrem), Group 2 (Geranomorphae), Huxley arrays two families thus:

- Family 1: *Gruidae*
Intermediate forms: *Psophia*, *Rhinochetus*
- Family 2: *Rallidae*
Intermediate forms: *Otis*, *Cariama*

He remarks thereon that he considered the cranes and the rails as constituting the typical forms of the group. The herons he places in a distinct suborder, the *Desmognathae*, in a group *Pelargomorphae*, containing the *Ardeidae*, the *Ciconiidae*, and the *Tantalidae*.

In the curious and unique classification of Garrod (P. Z. S., 1874, p. 116), we find his subclass *Homalogonatae* divided into numerous orders, the first of which is the *Galliformes*. This latter he divides into 'cohorts,' *x*, *B*, *y*, etc.,—Cohort B being the *Gallinaceae*, and it is thus divided:

- Family 1: *Palamedeidae*
- 2: *Gallinae*
- 3: *Rallidae*
- 4: *Otidae*
 - Subfamily 1: *Otidinae*
 - 2: *Phoenicopterinae*
- Family 5: *Musophagidae*
- 6: *Cuculidae*
 - Subfamily 1: *Centropodinae*
 - 2: *Cuculinae*

It is not surprising, in a classification of this nature, to find the herons in another Order, placed between the Cathartidae and Steganopodes, while the Gruidae are consigned to still a different order, from the rails, for example, and placed between the plovers and gulls (among the Limicolae), the only other cohort in the same Order being the Columbæ.

Order XVI of Doctor Scater's scheme is the Fulicariæ, which is created to contain (a) the Rallidæ, and (b) the Heliornithidæ. In the XVIIth he places the (a) Aramidæ; (b) Eurypygidæ; (c) Gruidæ; (d) Psophiidæ; (e) Cariamidæ, and (f) Otidæ. The Parridæ he places in Order XVIII—the Limicolæ.

Professor Newton, ever cautious and far-seeing in everything he did in ornithology—although the present writer does not always coincide with him in all his views, as in the present instance—places in the Herodiones the Ardeæ, the Ciconiæ, and the Plataleæ. Fulicariæ and Grues—the latter made to include the Gruidæ, Psophiidæ, Aramidæ, Eurypyga, and Phinochetus—make up the Grallæ.

Doctor Reichenow, who in 1882 gave us "Die Vögel der zoologischen Gärten," divides the Class Aves into 'Series.' Series III is the Grallatores, split up into orders, suborders, families, etc., and I extract the following from it:

Suborder B: Arvicolæ

Family 19: Otididæ

20: Gruidæ

Suborder C: Calamocolæ

Family 21: Rallidæ

Subfamily A: Rallinæ

B: Gallinulinæ

C: Parrinæ

Family 22: Eurypygidæ

Suborder D: Deserticoeæ

Family 23: Thinocoridæ

24: Turnicidæ

25: Pteroclidæ

Order VII: GRESSORES

Family 26: Ibirdæ

27: Ciconidæ

28: Phoenicopteridæ

29: Scopidæ

30: Baloenicipidæ

31: Ardeidæ

In 1884 appeared the second edition of Doctor Coues's 'Key' to North American birds, and in it we meet with the following scheme:

<i>Order</i>	<i>Suborders</i>	<i>Families</i>	<i>Subfamilies</i>
ALECTORIDES	Gruiformes	Gruidae	{ Rallinae Gallinulinae Fulicinae
	Ralliformes	Aramidae	
		Parridae	
		Rallidae	

This is one of the most natural arrangements I have met with, and in most particulars closely agrees with what I will probably have to suggest in the sequel, excepting the position of the Parridae.

Dr. Leonhard Stejneger in 1885 proposed a classification in that now wellknown work "The Standard Natural History." In it he places the Jacanidae in his superfamily Scolopacoidae of the order Grallae, and the Gruidae, Aramidae, and Rallidae in another superfamily, the Gruioideae of the same order. The storks and herons are removed to another order, the Herodii.

In the first edition of the 'Check-List' of the American Ornithologists Union, the following scheme is given:

<i>Order</i>	<i>Suborders</i>	<i>Families</i>	<i>Subfamilies</i>	<i>Genera</i>
PALUDICOLAE	Grues	Gruidae		Grus (3 sp.)
		Aramidae		Aramus (1 sp.)
	Ralli	Rallidae		Rallus (6 sp.)
				Porzana (5 sp.)
				Crex (1 sp.)
			Gallinulinae	Ionornis (1 sp.)
				Gallinula (1 sp.)
			Fulicinae	Fulica (2 sp.?)

Here the Jacanidae are placed as the last family of the Limicolae.

Fürbringer places the Parridae in a gens Parrae of a suborder Charadriiformes, which belongs to his order Charadriornithes. Between this order and the order Alectorornithes we find inserted two intermediate suborders, thus:

<i>Suborder</i>	<i>Genus</i>	<i>Family</i>
Gruiformes	Eurypygae	Eurypygidae Rhinochetidae Aptornithidae
	Grues	Gruidae Psophiidae Cariamidae
	Fulicariae	Heliornithidae Rallidae
	Hemipodii	Mesitidae Hemipodiidae

The late Doctor Sharpe, in his exceedingly useful "Review of recent attempts to classify birds," also places the Parrae in an order Charadriiformes (Order XVIII), while the Grues and Arami are in an order Gruiformes, along with the Rhinochetides, Mesitides, Eurypygae, Psophiae, and Dicholophi (Order XIX).

Dr. Hans Gadow, who has accomplished so much in the morphology of birds, has given us at least two schemes of classification for the class. One of these appears in Brown's 'Thierreich' (Aves), and the earlier one in the P. Z. S. ('92, p. 229), a paper "On the classification of birds." In this latter he places the Parridae among the Limicolae, and divides his Gruiformes into the Eurypygae, Ralli, Grues, Dicholophi, and Otides.

There are a number of others we might quote, but enough has been presented for my purpose: to show that a great variance of opinion still exists among the best authorities on the subject, but that the tendency seems to be to keep the Gruidae, the Rallidae, and the Aramididae more or less closely together, and well removed from the herons and storks and ibises, while the Parridae are placed among the limicoline forms, more or less near the plovers.

We will next proceed to examine the osteology of several forms representing such genera as Grus, Rallus, Crex, Ionornis, Gallinula, and Fulica. As long ago as July, 1888, I printed an account of the osteology of the sora rail; and as that contribution is now probably well known to comparative anatomists, I will not reproduce any part of it here beyond making references to

it in the course of the comparisons to be made with *Crex*, *Rallus*, etc., further on in the present paper.¹

My ability to compare the skeleton of our sora rail (*Porzana carolina*) with the corn crake of Europe (*Crex crex*) is entirely due to the kindness of Dr. F. E. Beddard, F.R.S., Prosector of the Zoological Society of London, who, with great generosity, presented me with a fine skeleton of the latter railine form. Such a comparison need not detain us long, for the osteological characters that distinguish *Crex* and *Porzana* are but a kind of distinguishing two genera osteologically, while, as a matter of fact, in many of their skeletal characters, these two short-billed rails are very much alike. Indeed, to such an extent is this the case, and so gradually do the skeletal characters of *Crex* shade through those of *Porzana* to typical *Rallus*, that the distinction between 'land-' and 'water-rails' possesses, in such premises, no foundation in fact, the opinion of some authorities to the contrary.

Essentially, the corresponding characters of the skull and associated parts of the same are identical in *Crex* and *Porzana*, the former simply being of greater size, as the corn crake is about one-third larger than the Carolina rail. The same observation applies to all the elements of the shoulder-girdle. The scapulae in *Porzana* are, however, relatively somewhat longer and more curved. With regard to the ribs and spinal column, they are the same in these two genera, while a few differences are to be found in the *pelvis*. These are of interest. The most important one is the rising up of the mesial borders of the ilia anteriorly, to meet the superior edge of the sacral crista in *Crex* and not in the Carolina rail.

Passing to the sternum, we find but two good distinctive characters worthy of mention. Upon its dorsal aspect in *Crex* there is a median osseous bar extending from its anterior border abruptly downwards, and but slightly backwards, to fuse at its narrower end with the sternal body; this is absent in *Porzana*.

¹ R. W. Shufeldt. Osteology of *Porzana carolina*, Jour. Comp. Med. and Surg., New York, July, 1888, vol. 9, no. 3, art. 17, pp. 231-248; numerous cuts in text.

In *Crex*, too, the body of the sternum is both actually and relatively larger than it is in the Carolina rail, while its lateral xiphoidal processes are drawn more closely towards the free external margins of the sternal body behind. This last character is to be well noted. Aside from the matter of size, the characters seen in the skeleton of the *pectoral limb* are essentially the same in the two genera, while a few distinctive ones are found in the *pelvic limb*. For example, the cnemial crests of the tibio-tarsus are more conspicuously developed in *Porzana* than in *Crex*, while the several joints of pes in *Porzana* are comparatively slenderer and actually longer than they are in the corn crake.

In comparing the lengths of the corresponding long bones of the *upper extremity* in these two genera, the differences are very well marked. In the case of the corresponding bones in the *lower extremity*, the difference, with respect to lengths, is but slightly in favor of *Crex* in any particular case. The femora form an exception to this last statement. It can be shown thus:

	<i>Humerus</i>	<i>Femur</i>	<i>Tibio-tarsus</i>	<i>Metatarsus</i>
<i>Crex</i>	45 mm.	49 mm.	65 mm.	41 mm.
<i>Porzana</i>	36 mm.	37 mm.	60 mm.	38 mm.
Differences in length.....	9 mm.	12 mm.	5 mm.	3 mm.

The *patellae* are absent both in *Porzana* and in *Crex*.

Fulica, *Ionornis*, and *Gallinula* are all genera that have characters in their skulls and associated skeletal parts which essentially agree with the corresponding ones in *Porzana*. So slight are the differences that, were we to be guided by these parts of the osseous system alone, it would be impossible to find even characters for generic distinctions to separate the forms in question. They will each and all constitute examples to show that the skull in birds is not always an all-sufficient guide to correct taxonomy, much less a never-failing index of remote or near affinities in this class of vertebrates. The skull in *Fulica* might be attached to a skeleton of a *Porzana*, of a size corresponding to that of the former; and there is not an ornithotomist, living or dead, who would for an instant believe it was the slightest shade out of the way. It would simply be regarded as having come

from a very large-sized Porzana, and assigned to that genus as a matter of course.

Coots (Fulici) and Gallinules (Gallinula) have, too, the same character in their vertebral column, ribs, shoulder-girdle, and sternum that we found in Crex and Porzana. In the sternum of Fulica, the lateral ziphoidal processes are long, and slightly inclined to flare outwards more than they do in the Carolina rail; and a manubrial process is also better developed, although it is still very small.

Coming to the *pelvis*, we find Fulica has the preacetabular parts of the ilia as we find them in Porzana; but the pelvis is actually as well as relatively longer and narrower in the first-named genus. The lateral postacetabular projections are not so well marked, while the pubic styles are quite different from what we have described for those parts in Porzana. They each become broader as they proceed backwards, until they are met by a conspicuous out-turned process, given off by either ischium at its postero-inferior angle. At this point, a pubic style turns abruptly downwards, and is continued for some little distance to its truncate free posterior extremity. This downbent portion is broader and flatter than the style is at its commencement beneath the cotyloid cavity. On the dorsal postacetabular surface of the bone, the parial and scattered inter-diapophysial foramina are usually entirely absent in Fulica, and always so in the skeletons of adult Gallinules. Otherwise the pelvis in Gallinula closely coincides with that part of the skeleton in Porzana, with the exception of the ilia meeting the sacral crista; in that particular it is more like the pelvis of Crex.

The *appendicular skeleton* in the coots and Gallinules is distinctly ralline in character. They lack patellae in the pelvic limbs, the several bones in Gallinula being more like the corresponding ones in Crex than in Porzana; the reverse of this is the case for Fulica. An example of this is well seen in the development of the *cnemial crests* of the *tibio-tarsus*, they being much suppressed in Gallinula, as they are in the corn crake, while in a coot they are conspicuously developed, as we find them in the Carolina rail.

From these short thick-billed ralline birds, the passage to the long and comparatively slender-billed representatives of the genus *Rallus* is easily made. To illustrate this latter genus I have before me skeletons of both *Rallus longirostris crepitans* and *R. l. obsoletus*.² A glance at either of them is sufficient to satisfy us that they are closely related to the forms we have already passed in review above.

In *Rallus l. crepitans* all the characters of the skull and associated skeletal parts are typically ralline, agreeing with what we found in *Porzana*. The chief difference to be noted is an elongation of the bones of the frontal portion of the skull, but more particularly the bones of the face and the mandible. This latter gives the bird its long beak and the elongate external narial apertures. Another point to be noticed is the well-marked, though narrow supra-orbital glandular depressions. These are confined to the entire superior margin of either orbit, and are very faint in *Porzana* but slightly better marked in *Fulica*.

As in *Fulica*, *Rallus* has much better defined temporal fossae; they are entirely restricted to the lateral aspects of the skull. In this species of *Rallus*, the maxillo-palatines may be in contact with each other in the median line; they are always very close to each other there in all true rails. The number and characters of the vertebrae between the skull and the pelvis, as well as the number and general arrangement of the ribs, agrees with the Carolina rail and with *Crex*.

The *shoulder-girdle*, the *sternum*, and the *pelvis* of this species of rail also agree exactly with what we find in *Crex*, and this is an interesting fact. The limb bones are more like those in the corn crane also than those of either *Porzana* or the coots and *Gallinules*. In other words, *Crex* stands between *Rallus* and *Porzana*, rather than between *Porzana* and the *Gallinulinae*, to which latter place it has been incorrectly assigned by some authorities.

² For the first-named species I am indebted to Mr. Philip Laurent, of Philadelphia, and for the last-named to Dr. T. S. Palmer, of the U. S. Dept. of Agriculture, who collected the material for me at Berkeley, California, for use in the present connection, and my thanks are here tendered to him and to Mr. Laurent for their timely assistance.

With respect to the osteology of *Aramus vociferus*, I have already written a complete and fully illustrated account of the skeleton of that puzzling species (*The Anatomical Record*, vol. 9, no. 8).

OSTEOLOGY OF *GRUS AMERICANUS* AND OTHER CRANES
OF THE GENUS *GRUS*

Of the genus *Grus* I have before me, at this time, a complete, disarticulated skeleton of *G. americanus*, a complete skeleton of *G. mexicana*, and two extra skulls of *G. canadensis*. For this

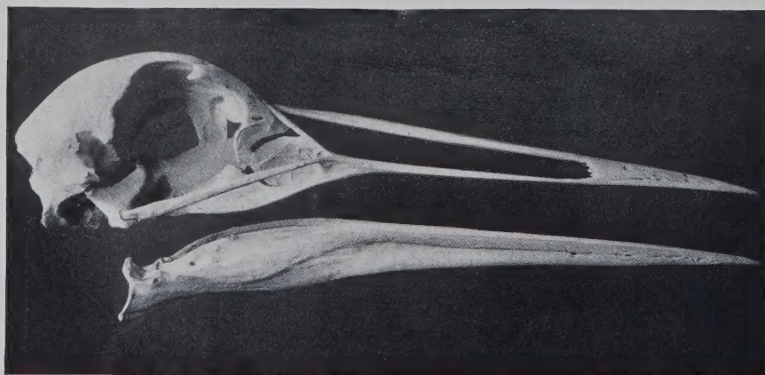


Fig. 1 Left lateral view of the skull and mandible of the little brown crane (*Grus mexicana*); photographed by the author, natural size; reduced in reproduction to three-fifths; Specimen No. 820, Coll. U. S. Nat. Museum.

material I am indebted to the U. S. National Museum, of Washington, D. C., and from its examination I am enabled to demonstrate the following facts:

The skull. Except in point of size, the skull of *Grus canadensis* presents the same characters as those found in *G. americanus*, the latter being about one-third larger, and lacks the sculpturing along the superior orbital margins for the nasal glands.

There is but little else to be said here about the skull of this crane, as I incidentally described it when writing out the above-mentioned account of the skull in *Aramus*. Special attention is invited, however, to the additional perforation above the central

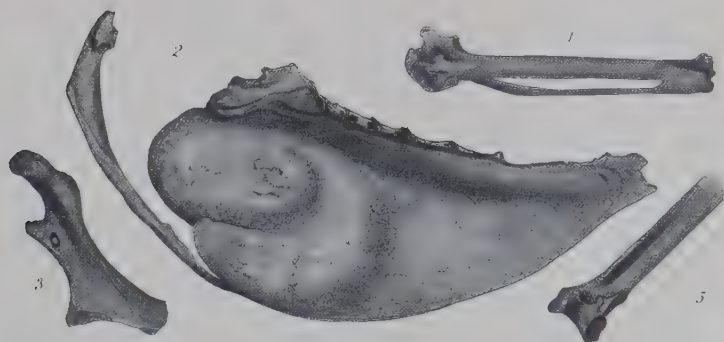


Fig. 2 Left lateral view of the sternum and os furcula of *Grus mexicana*. Fig. 3 Left coracoid, anterior aspect. Fig. 4 Left carpo-metacarpus, anconal aspect. Fig. 5 Left tibio-tarus, distal portion on anterior aspect. Figures 3-5 are all from the same skeleton that furnished the sternum in figure 2 (No. 820, Coll. U. S. Nat. Mus.). Drawn by the author, natural size, and here reduced to two-fifths.

one in the interorbital septum, and to the large, leaf-like maxillo-palatines; these are entire, though very thin. Another point is the peculiar manner in which the descending part of the *lacrymal* stands out at right angles to the rest of that bone, not approaching the zygoma as it does in so many other birds where it is found, and as it does to a great degree in *Aramus*. This is likewise the case in *Grus mexicana* (fig. 1).

In the *mandible* of this crane I find the ramal vacuities nearly filled in by the splenial elements, and its symphysis is wider than it is in the limpkin, which gives rise to a wider longitudinal groove upon its upper side. Hardly any evidence of a coracoid process exists in the lower jaw of either of these birds, the merest tubercle being present at the site where it is commonly found on the superior ramal border. In both *Aramus* and *Grus*, this part of the skull is only partially pneumatic, and the pneumatic foramina at the supero-mesial aspects of the inturned processes of the articular ends are always single and small.

Of the remainder of the axial skeleton. When Garrod gave us his account of the anatomy of the limpkin, in a paper in the Proceedings of the Zoölogical Society of London ('76, pp. 275-

277), which he entitled "On the anatomy of *Aramus scolopaceus*," he remarked of the bird: "The sternum is completely Gruine, as are the other parts of its skeleton" (p. 275), by which he meant, I presume, in a general way; for if he meant anything else by the word 'completely,' what he said will by no means strictly apply to *Grus americanus*, as may be seen from what follows.

Now I have shown in my former paper that *Aramus* has 23 vertebrae between skull and pelvis; *Grus americanus* has one more than this—24. They are all highly pneumatic, and each one is about double the size of its corresponding representative in the spinal column of *Aramus*, so far as the latter can be satisfactorily ascertained or determined.

The first *eleven* cervical vertebrae in *G. americanus* have exactly the same characters as the first eleven in the column of *Aramus*; but from that point on, as we pass from vertebra to vertebra, we come to appreciate the fact that a change is slowly taking place. The 12th cervical is relatively shorter in *Aramus*, and its neural spine, or rather eminence, is longitudinally divided; not so in *Grus*. These differences still obtain in the 13th, while in the 14th the neural spine in *Aramus* is represented by a remarkable saddle-shaped enlargement, and the hypapophysial canal is replaced by a spine. This canal in the 14th vertebra of the crane is still continued, and the neural spine is a low, median eminence near the center of the centrum. Again, these differences are carried on to the 15th vertebra, wherein the peculiarly enlarged neural eminence of this one in *Aramus* lends to the bone a most extraordinary appearance. Strange to relate, the 16th cervical in these two birds have the same identical characters. To some extent, this also applies to the 17th in each; but the 17th in *Aramus* bears a pair of free cervical ribs of no mean length, while the pleurapophyses in this vertebra in *Grus* are short and fused with the bone. In *Grus* the 18th and 19th vertebrae are still free, and the 18th supports the first pair of free ribs; they do not connect with the sternum as they do in the case of the 19th. In *Aramus* the 18th vertebra is fused with two others, and, by means of haemapophyses, its ribs do con-

neet with the sternum. From this point on, to include the pelvis, the sternum, and other parts of the axial skeleton, the skeleton in *Grus* differs so much from what we find in *Aramus*, that a more exact description is required for the former. In *Grus americanus*, the 20th, 21st and 22d vertebrae of the spinal column are coössified so as to form a single bone. In it the neural canal is markedly small in caliber, while a large *pneumatic canal*, of fully three times its size, occurs above it. It is almost entirely unobstructed by any slender osseous trabeculae. Nothing whatever of this nature occurs in *Aramus*. This canal is open at both ends, and the entire bone otherwise is more or less riddled with pneumatic openings. Very extensive ossification of the tendons attached to it upon its neural aspect has taken place, and they lead forwards and backwards as lengthy interlacements.

The 23d and 24th vertebrae in the column of *Grus americanus* are again free, and are remarkable bones in many particulars. The lofty neural spines are quadrilateral in form, and great, lengthy, osseous rodlets, with fringed ends, project directly forwards and backwards from their superior borders. Similar coössified tendons, directed in the same manner, are found on the supero-external aspects of the diapophyses. The neural canal is particularly small, when we come to take the size of the bird into consideration. The *pneumatic canal* above it, which is completed by the neural arches, is, like the neural canal, a cylindrical passage, but has certainly five or six times the caliber, and is filled with a very open, spongy, osseous tissue. Of especial interest are the forms assumed by the post- and prezygapophyses. Antero-posteriorly, they are exceedingly narrow, while at the same time they are very long. Both in front and behind the mesial ends of the pair meet, and make an angle with each other of about ninety degrees. Lying in the middle line, the apex of this angle is found in the periphery of the entrance to the neural canal, at its highest dorsal point. The aperture of the angle embraces the immediate entrance to the 'pneumatic canal' described above—the whole being in a plane perpendicular to the longitudinal axis of the centrum. The mesial ends of the prezygapophyses of the 23d vertebra do not quite meet with each

other; the articular surfaces are upon their upper aspects. This is their character also in the next succeeding vertebra; but in both of these the mesial ends of the postzygapophyses do meet, and the articular surfaces of them have the appearance of being continuous.

The *general form* of the *pelvis* in *Grus americanus* is the same as we see in the pelvis of *Aramus*, but there are to be found a few differences in details. In front, the antero-mesial margins of the ilia are so rounded off that they fail to meet the superior border of the fore part of the sacral crista to more than the extent of the neural spine of the first vertebra composing it. In the post-acetabular region small perforating foramina are seen among the diapophyses of the vertebrae. Some of these have a parial arrangement, and some are scattered. Upon lateral aspect of the bone we are to note how, upon either side, the ilium is produced as a conspicuous ledge overhanging the antitrochanter and the ischiadic foramen. A much smaller ledge of this kind is found just before the ilium terminates posteriorly; the two are separated by a considerable interval. This formation is the very reverse of what we find in the Rallidae. Turning to the under side of the pelvis of this crane, we find that it is *seven* of the leading vertebrae that throw out their lateral processes, to fuse by their other ends with the ventral surface of the ilium upon either side, instead of only *five* as in *Aramus*. Then follow *three* more, which have their apophyses thrown directly upwards against the pelvic roof, being thus concealed entirely upon direct ventral view. The 35th vertebra of the spinal column in this specimen, on its left side only, sends out a weak parapophysis, to reach over to the pelvic wall just above the cotyloid ring. But in the last *six* (*five* in *Aramus*) 'sacrals,' or true sacral vertebrae plus 'urosacrals,' these lateral apophysial braces are big and strong, and have their outer ends, and the adjacent ventral surfaces of the pelvic basin, all indistinguishably fused into one mass at their several points of meeting. Other characters of the renal fossae in *Grus* agree, in the main, with what we find in *Aramus*.

Both the pygostyle and the last two or three caudal vertebrae,

in this museum specimen of *Grus*, have been lost (or cut off by the taxidermist), and I have but the leading four vertebrae of the skeleton of the tail before me. Judging from these, however, one is enabled to say that they are more highly pneumatic than they are in *Aramus*, but that there is the same stunting of the outstanding processes and spines as in that genus. And all these vertebrae are very small compared with those in the pre-pelvic part of the vertebral chain.

It has already been said above that the 18th vertebrae supports a pair of free ribs. They are pneumatic, nearly 3 cm. long, and without unciform processes and haemapophyses. Both these latter characters pertain to the ribs of the 19th vertebrae, and the unciform appendages may anchylose to the borders of the ribs, though this is not the case with those in the middle of the dorsal series. Vertebrae 20 to 23 also have fully developed, highly pneumatic ribs, all connecting with the sternum by costal ones.

Then there are three pairs of pelvic ribs; but the haemapophyses of the ultimate pair fail to have their costal ribs quite reach the sternum. Nothing peculiar marks any of these free pleura-pophyses of the dorsal region; if we select one from the middle of the series, we find it considerably curved so as to conform to the outline of the thorax. It is constricted opposite the facet for the large, flake-like epipleural process; while from this point, both in the dorsal and ventral direction, it very gradually widens again. But at the best, these are narrow, though at their lower ends they become sufficiently broad to support a pretty good-sized facet for the costal rib.

The last pelvic pair of all are very long and slender, and at their vertebral ends they are more or less rudimentarily developed—the tubercles being entirely aborted.

Grus americana, as well as *Grus mexicana* (fig. 2), has its os furcula completely fused with the *sternum* at the carinal angle, the point of fusion being broad and firm.

The 'body' of the sternum is long and narrow as in *Aramus*; its xiphoidal margin is inclined to be a little jagged, and presents no definite pattern of notching. The thoracic aspect of the

sternal body is more generally and roundly concaved than it is in *Aramus*, and the pneumatic foramina far more open. Small air-holes of this kind absolutely riddle the bone upon this surface in front. They are found upon either side of a prominent median mound which exists in this locality, it being the supero-external evidence of the coiling of the windpipe within the carina, to which reference will be made presently. This crane has *seven* haemaphysial facettes upon either costal border, to the *six* found there in *Aramus*. Its costal processes are very low, curl outward, and each is squarely truncated. The anterior border of the of the body of the bone is thickened, and upon either side of the median mound spoken of above, it overhangs the fossae it contributes to form in those localities; and it is within these fossae or recesses that the very numerous pneumatic perforations are seen, to which reference has just been made.

The 'coracoidal grooves' are very extensive, and are the same in general character as they occur in the limpkin, except that in *Grus* they *do not decussate*.

Below, the carina extends the entire length of the sternal body; transversely it is very thick, but this part is entirely hollowed out for two very different purposes. These are: the admission of air to the posterior moiety, while anteriorly a chamber is created in which the trachea is once or twice looped and coiled.

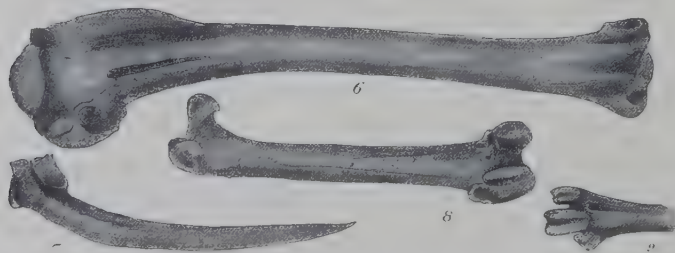


Fig. 6 Anconal aspect of the right humerus of *Grus mexicana*. Fig. 7 Right scapula, dorsal surface. Fig. 8 Left femur, posterior aspect. Fig. 9 Distal extremity of the right tarso-metatarsus, anterior view. These bones are all from the same skeleton that furnished those seen in figures 2-5 (antea; No. 820, Coll. U. S. Nat. Mus.). Drawn by the author, natural size, and here reduced to two-fifths.

The latter room, however, is not sufficient for the purpose just mentioned, so the cavity has ossified by extension far out in front, appearing as a median, rounded, transversely-compressed, closed protuberance between the costal grooves and the point below where the trachea enters the carina. The tracheal loop which is lodged in this part is the continuation of the same that passes round through the median mound on the thoracic aspect of the body of the sternum, to which I have already made reference above.

The sternum I have just described is, as stated above, from a specimen of *Grus americanus*, but the arrangement of the tracheal coils within the carina exist very much as they are seen in the figure showing them for *Grus mexicana* (fig. 2). Age and sex may have something to do with this; and a great many more sterna of these birds, at all ages, must be examined before the complete and full account of this very interesting feature can be written out. No such material is at hand at this writing.

Os furcula, as I have already stated, is, in *Grus americanus*, fused below with the angle of the carina of the sternum. It is quite a differently characterized bone as compared with the *os furcula* of *Aramus*. In the first place, it is more on the V-order of pattern than on the U; its rami are far more cylindrical; indeed, in the limpkin the rami are very decidedly flattened, and its free clavicular ends are very differently fashioned from those parts as found in the latter bird. Here, in *Grus*, they are pointed at their extremities. The articular facets situated *below* these points are comparatively very small; while below them, again, about a centimeter down either ramus, we meet with a moderate, more or less abrupt swell in the bone, which gradually dies away about half way down towards the symphysis. These enlargements occur upon the antero-external border of the clavicular ramus of either side—a border the more easily defined here by the very distinct muscular ridge-like lines that pass longitudinally down over the ramal surface. This clavicular fourchette of *Grus* differs quite as much from that bone as seen in *Aramus*, as the one in the latter differs from the bone in *Rallus*.

Apart from the great differences in size, the *coracoids* and

scapulae in *Grus americanus* simply repeat, in all their essential characters, the corresponding elements of the shoulder-girdle as they are found in *Aramus*. When articulated *in situ*, however, the end of the clavicle on either side does not come in contact with the scapula.

A *scapula* in *Grus americanus* has just twice the length of that bone in the limpkin, and it is not as much curved; while the pneumatic foramen on the under side of its head is very large and deep. There is a large pneumatic foramen, too, on the posterior aspect of the expanded sternal portion of either *coracoid* in *G. americanus*, and these bones, in this species of crane, are relatively much shorter and stouter than are the coracoids of *Aramus*; otherwise they have the same form and character.

So far as the axial skeleton is concerned, then, in the genera here compared, we can hardly say with Garrod that the "sternum in *Aramus* is completely Gruine, as are the other parts of its skeleton," for the differential characters are too marked, too important, and too numerous, when we come to regard them carefully in such representatives as *Aramus vociferus* and *Grus americanus*.

The appendicular skeleton. Little requires to be said here upon this subject, as the various bones were practically described during the comparisons made, on a former page, with those of the pectoral and pelvic limbs of *Aramus*. All the essential characters of the skeleton of the arm as seen in *A. vociferus* are repeated in the corresponding bones of that limb in *Grus*.

In the lower extremity we find, in the *femur* of *Grus*, a very deep 'rotular channel' between the condyles in front, and posteriorly there is constantly seen above the fibular groove of the external condyle a small, concave excrescence, to which is attached in life the femoral head of the *flexor perforans digitorum profundus* muscle.³ Only a slight roughness occurs upon the femur at the same site in *Aramus*.

Tibio-tarsus and *fibula* have identically the same morphological characters in the two genera. In the *tarso-metatarsus*, the groove seen in the hypotarsus of that bone in *Aramus* is com-

³ Myology of the raven, p. 167, fig. 46, a. Macmillan and Co., London, 1890.

pletely sealed over in *Grus*, converting it into a cylindrical perforation passing vertically through the center of the projection. In addition, the back of the hypotarsus is shallowly grooved in two or three places for the passage of tendons. At the posterior aspect of the shaft the outer edge of the tendinal groove is, for its middle third, elevated as a conspicuous crest in this crane, and it serves well to keep the ossified tendons in the channel where they belong. For the rest, these bones in the two genera under consideration have similar characters.

Joints of the phalanges of *pes* are relatively much stouter and shorter in *Grus* than they are in *Aramus*; in other words, the skeleton of the foot in *Aramus*, in so far as the toes are concerned, is markedly ralline in type, notwithstanding the fact that all the other bones of its pelvic limbs, with the exceptions mentioned, are so typically gruine.

In my former brief abstract of the osteology of the birds which have been compared in the present paper, I published a 'synoptical table,' in which the skeletal characters of *Rallus longirostris*, *Aramus vociferus*, and *Grus americana* were critically compared in parallel columns. As stated above, this paper appeared a great many years ago in the *Edinburgh Journal of Anatomy*; and as that publication is to be found in the majority of the larger scientific libraries in America, and is therefore accessible to students of avian osteology in this country, the aforesaid table has been omitted in the present contribution.

CONCLUSIONS

In so far as the rails, cranes, and their allies, are concerned, as they are represented in North America and other regions where they occur, they are allied or related to each other as I have, in the main, provisionally pointed out in another contribution,⁴ thus:

⁴ R. W. Shufeldt. An arrangement of the families and higher groups of birds. *Amer. Nat.*, vol. 38, nos. 455-456, Nov.-Dec., 1904, pp. 833-857. The part of the classification referred to is to be found on pages 851-852. As this classification of birds first appeared (that is, in the paper here cited), the family *Aramidæ* was arrayed among the *Ralliformes*, while here it is placed among the *Grues*, where it really belongs.

Supersuborder	XII	GRUIFORMES	Supersuborder	XIII	RALLIFORMES
Suborder	XIX	Grues	Suborder	XX	Fulicariae
Superfamily	I	Gruioidea	Superfamily	I	Heliornithoidea
Family	I	Gruidae	Family	I	Heliornithidae
	II	Aramidae	Superfamily	II	Ralliodea
	III	Psophiidae	Family	I	Rallidae
Superfamily	IV	Cariamoidea			
Family	I	Cariamidae			
Superfamily	III	Eurypygoidea			
Family	I	Eurypygidae			
	II	Rhinocetidae			
	III	Mesitidae			
	IV	Aptornithidae			

These groups are arrayed between the supersuborders Stereornithiformes and the Apterygiformes, where they naturally belong.

My examination of the skeleton of the courlans demonstrates the fact that, in that part of their anatomy at least, those birds have the gruine characters predominating. But these gruine characters are not always typical, and the departures seen are frequently of a class that distinguish families among birds rather than genera. This settles the position of the courlans in the system as a family—the Aramidae of the crane-group (Grues).

In the A. O. U. "Check-List of North American Birds," published in 1895 (second edition), it will be noted that the Aramidae was placed as a family among the Ralli or rail-group; and that after my paper appeared in the *American Naturalist* ('04) it was removed, as a family, to the crane-group (Grues), where up to this writing, it has been very properly retained. There are not a few similar errors yet to be rectified in that surely not-up-to-date volume. However, its last edition has the Rallidae properly and naturally arranged—a fact upon which we may congratulate ourselves, perhaps all the more for the reason that the Grues have also been relegated to their true position in the system in that work ('10).

As elsewhere pointed out, Fürbringer is of the opinion that the Apteryges are far more closely related to the Ralliformes than has heretofore been realized; and if this proves to be true, another linking line for the cranes and rails leading to the generalized struthious types is in evidence, with all the gallinaceous birds more or less related.

THE GROWTH AND VARIABILITY IN THE BODY WEIGHT OF THE ALBINO RAT

HELEN DEAN KING

From the Wistar Institute of Anatomy and Biology

FIVE FIGURES

For several years investigations have been in progress in the animal colony of The Wistar Institute for the purpose of ascertaining the environmental and nutritive conditions most favorable for the development of the rat. The very flourishing state of the colony at the present time seems to indicate that these investigations have solved the problem of the care and breeding of this animal, and that in future it will be possible to supply a 'standardized' type of rat for laboratory use.

Growth records for the body weight of the albino rat have already been given by Donaldson ('06) and by Jackson ('13), but it seems worth while to publish additional data obtained from a study of a series of rats bred in The Wistar Institute colony in order to show the rapid and continuous growth of this animal in response to a particularly favorable set of environmental conditions. It is hoped that these records may also serve as standards with which the body weights of various strains of rats, raised under similar conditions, may be compared.

The thirteen litters used in this study were taken from the general colony of albino rats kept as 'stock' supply. In choosing the litters care was taken to select only those in which the individuals were of good size at birth and appeared strong and vigorous. The animals used, therefore, represent the best stock in the colony. A random selection of any stock litters available for the purpose in mind was not feasible, as experience has shown that rats that are small and weak at birth do not, as a rule, grow at a normal rate and that they usually die at an early

age: records from litters of this kind would have seriously affected the results.

Since the removal of young rats from the nest at or soon after birth often results in their being destroyed by the mother when returned, the first weighings were made when the litters were thirteen days old. As at this age differences in the weights of the members of the litter are usually very slight, individuals of the same sex were weighed together and the average weight of the group recorded. The rats were weighed in a similar way when they were thirty days old, but thereafter the individuals of the litters were weighed separately at intervals of one month. Records were taken over a period of sixteen months, by which time so many of the rats had died that the investigation was brought to an end.

Members of the same litter were kept together and allowed to breed. This, of course, introduced the possibility of an error in the records for the body weights of the adult females. In the rat pregnancy can usually be detected by the twelfth or thirteenth day, at which time, as Stotsenburg's ('15) records show, the average weight of each fetus is only about 0.04 grams. At this stage the increase in the weight of the female as a result of pregnancy is comparatively slight, and as females known to be pregnant were never weighed, the records have probably not been affected to any great extent by this factor. Only a very few of the litters cast were reared, and the weights of nursing mothers were not recorded if they were below those of the last weighing before pregnancy was noted.

In any series of weighings of live animals there is always an unavoidable error due to the presence of a greater or less quantity of undigested matter in the alimentary tract. To minimize this source of error in these records the rats were always weighed in the morning before they had been fed.

An illness of any kind has a marked effect on the body weight of the albino rat, and cases are not uncommon in which animals have lost 100 grams in weight in the course of two or three weeks. Except in very old rats, a steady loss in weight for a period longer than one month is an almost certain indication of a chronic disease

that will eventually kill the animal. The body weights of animals obviously ill were not used in making up the final records, and as far as known the body weights given in the accompanying tables are those of animals in good physical condition.

All the rats were reared under similar environmental conditions. The food given them was a 'scrap' diet consisting of carefully sorted table refuse which was fed once each day, while corn on the cob was always available as an extra ration. Each cage had an abundant supply of water, which was renewed daily to prevent contamination.

GROWTH IN BODY WEIGHT OF THE ALBINO RAT

In order to obtain a series of records that would represent the normal increase in the body weight with age it was considered advisable to take a sample of the stock at two different periods rather than to rear a large number of litters at one time. This plan has extended the work of collecting records over the greater part of three years, but it has amply justified itself since it has shown that, when environmental conditions are uniform, there is comparatively little variation in the rate and in the extent of growth of rats born in different years. Records for the growth in body weight obtained from one set of stock albino rats can therefore be used as 'standards' for the colony, as long as the animals are reared under similar external conditions.

The first series of rats used in this investigation comprised seven litters born between December 26, 1912 and March 10, 1913. These litters contained a total of 46 individuals, 23 males and 23 females. The average weight of the individuals of each sex, together with the extreme body weights for each age at which records were taken are given in table 1. Individual data for this and also for the second series of rats studied are filed at The Wistar Institute.

In a series of investigations recorded in a previous paper (King '15), it was found that the average body weight of stock albino males at birth is 4.6 grams, and that the average birth weight of the females is 4.5 grams. According to these records the male

rat is heavier than the female at birth, and, as shown in table 1, the male also exceeds the female in body weight at all ages at which data were collected, the difference in the weight of the two sexes becoming more marked as the animals grow older.

The growth of the albino rat is very rapid during the first 120 days of postnatal life, as Donaldson has already shown. After this age growth in body weight is relatively slow, as is

TABLE 1

Data on seven litters of stock albino rats, showing the increase in the weight of the body with age (Series 1)

AGE IN DAYS	MALES				FEMALES			
	Body weight in grams			No. indi- viduals	Body weight in grams			No. indi- viduals
	Average	Lowest	Highest		Average	Lowest	Highest	
13.....	18.2	16	21	23	16.0	14	20	23
30.....	49.7	43	60	23	47.4	40	57	23
60.....	131.0	87	170	23	113.2	77	153	23
90.....	188.5	125	238	23	148.9	99	178	16
120.....	230.3	146	284	23	173.1	125	197	17
151.....	252.1	196	307	23	181.0	152	215	18
182.....	268.0	195	343	23	197.5	147	245	21
212.....	276.0	221	366	22	192.3	136	245	18
243.....	281.7	194	355	21	200.2	141	256	19
273.....	270.6	202	344	20	203.0	158	248	16
301.....	281.4	198	366	13	201.1	165	230	18
334.....	291.1	238	368	16	212.4	178	239	17
365.....	301.7	248	370	12	214.2	176	247	15
395.....	310.0	254	381	9	213.7	178	247	15
425.....	316.3	255	368	8	207.9	169	238	12
455.....	316.0	249	349	6	215.2	196	242	7
485.....	313.5	255	374	3	219.5	210	241	4

indicated by the data in table 1. Increase in body weight does not entirely cease when the rats have reached maturity, and it usually continues as long as the animals are in a healthy condition. The later weight increase, however, is not true growth, but chiefly the accumulation of adipose tissue, as is the case in many other forms.

The second series of rats used in this study consisted of six litters, born during the first week of October, 1913. These lit-

ters contained a total of 54 individuals, equally divided as to sex. Growth data for this series of rats are given in table 2.

The growth records obtained for this series of rats are so nearly like those for the rats of the first series that the rate and extent of body growth in the individuals of the two series can best be compared through the growth graphs constructed from the average body weight of the animals as given in table 1 and in table 2.

TABLE 2

Data on six litters of stock albino rats, showing the increase in the weight of the body with age (Series 2)

AGE IN DAYS	MALES				FEMALES			
	Body weight in grams			No. indi- viduals	Body weight in grams			No. indi- viduals
	Average	Lowest	Highest		Average	Lowest	Highest	
13.....	16.4	13	18	27	15.3	13	18	27
30.....	47.4	41	54	27	44.2	39	50	27
60.....	116.0	64	149	27	101.8	66	124	27
90.....	181.6	103	226	27	147.7	95	177	23
120.....	217.1	151	274	27	173.7	132	212	25
151.....	238.6	169	294	27	189.8	147	225	27
182.....	250.1	172	303	27	195.1	149	232	21
212.....	261.3	176	324	26	201.4	167	238	24
243.....	277.8	206	334	23	216.5	171	256	24
273.....	290.7	218	349	21	216.6	170	254	22
304.....	310.8	220	379	18	235.2	177	262	20
334.....	309.8	240	385	17	231.8	170	276	18
365.....	310.6	245	377	16	231.6	177	276	16
395.....	317.4	246	376	15	226.9	175	284	16
425.....	310.0	243	397	15	221.0	178	271	18
455.....	329.2	289	414	9	223.4	198	264	11
485.....	330.3	276	437	9	241.4	197	324	9

Chart 1 shows the growth graph for the 23 males belonging to the first series and also the growth graph for the 27 males of the second series of animals studied. In this, as in other charts where the graphs would properly run very close together at the beginning, the distance between the graphs has been slightly exaggerated in order to keep the lines distinct.

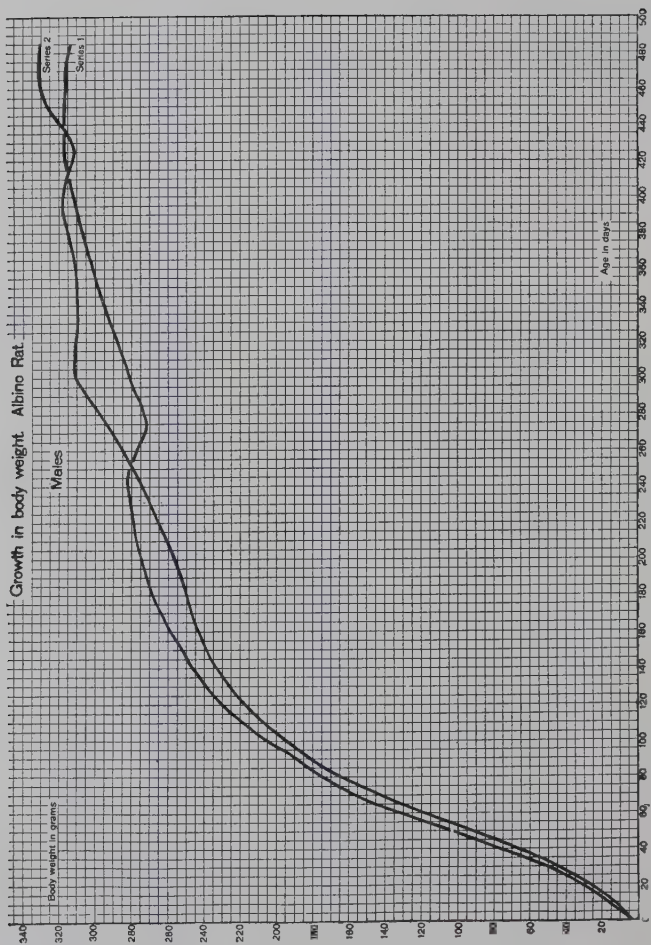


Chart 1 Graphs showing the growth in body weight of two series of stock albino males (data in tables 1 and 2).

In this chart the growth graph for the males belonging to the second series runs somewhat below that for the males of the first series until the rats have reached 240 days of age. The two graphs cross at this point and the graph for the second series then runs above the other until the end, except for a slight dip at the 425 day period. The pronounced drop in the graph for the first series that occurs at 280 days is not to be considered as normal. It is due to the fact that, when the majority of the rats in the series were about eight months old, the animals were removed to new quarters and the change, which unfortunately took place during a spell of cold, damp weather, so affected the animals that many of them, particularly the males, did not show a normal gain in body weight for about two months.

Graphs for the females of the two series, constructed from the average body weights as given in table 1 and in table 2 are shown in chart 2.

Growth graphs for the females belonging to the two series bear about the same relation to each other as do those for the males. The graph for the second series runs slightly beneath that for the first series in the beginning, it meets the other graph at the 120 day period, and subsequently runs higher for the remainder of its course. There is no drop in the graph for the females of the first series comparable to that found in the graph for the males at the 280 day period. The change of quarters which so adversely affected the growth of the males seemed to have had so little effect on the females that the growth graph has not been lowered at any point.

In both chart 1 and in chart 2 the growth graphs for the two series of rats born nearly a year apart run very close together throughout their entire length. This indicates that, when environmental conditions are uniform, the growth of stock albino rats takes a very definite course and tends to produce animals having a like weight at any given age.

To summarize the results the growth data for all the individuals in the two series are combined in table 3. From the average body weights given in this table the graphs in chart 3 have been constructed.

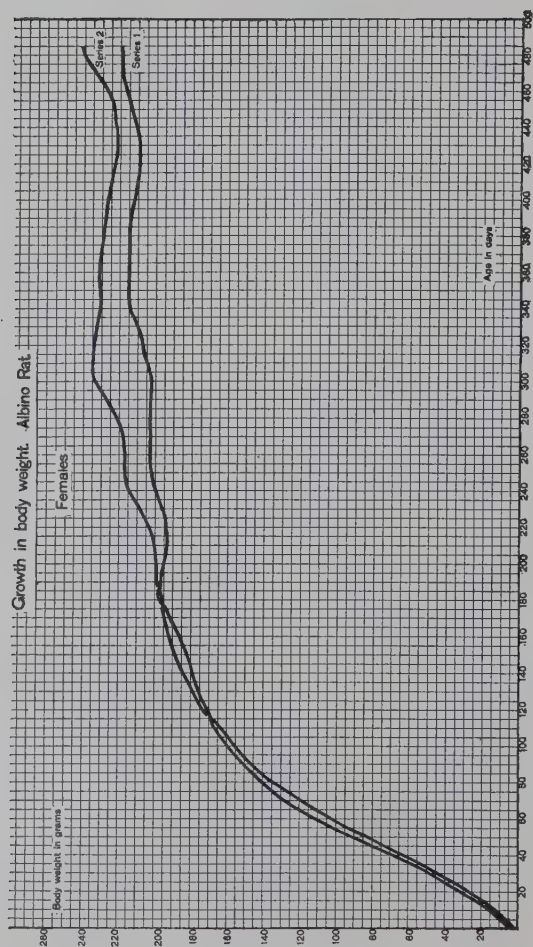


Chart 2 Graphs showing the growth in body weight of two series of stock albino females (data in tables 1 and 2).

A comparison of the graphs shown in this chart brings out very clearly the great difference between the growth of the male and that of the female rat. The graphs run very close together until the 60-day period. At this point they begin to diverge rapidly, the graph for the males soon appearing far above that for the females. At 200 days of age the average weight of the males is

TABLE 3

Data on thirteen litters of stock albino rats, showing the increase in the weight of the body with age (summary of the data in table 1 and in table 2)

AGE IN DAYS	MALES				FEMALES			
	Body weight in grams			No. indi- viduals	Body weight in grams			No. indi- viduals
	Average	Lowest	Highest		Average	Lowest	Highest	
13.....	17.2	13	21	50	15.7	13	20	67
30.....	48.5	41	60	50	45.7	39	57	50
60.....	122.9	64	170	50	107.1	66	153	50
90.....	184.8	103	238	50	148.0	95	178	39
120.....	223.2	146	284	50	173.4	125	212	42
151.....	244.8	169	307	50	186.3	147	225	45
182.....	258.4	172	343	50	196.5	147	245	42
212.....	268.0	176	366	48	197.3	136	245	42
243.....	279.7	194	355	44	209.6	141	256	43
273.....	280.9	202	349	41	210.8	158	254	38
304.....	296.1	198	379	36	219.1	165	262	38
334.....	300.8	238	385	33	222.4	170	276	35
365.....	306.1	245	377	28	223.1	176	276	31
395.....	314.1	246	381	24	220.5	175	284	31
425.....	312.2	243	397	23	215.8	169	271	30
455.....	323.9	249	414	15	220.2	196	264	18
485.....	326.0	255	437	12	234.7	197	324	13

about 50 grams more than that of the females (table 3), and this difference, as the growth graphs in chart 3 show, tends to become still greater as the animals grow older.

The growth of the albino rat in body weight has been studied by Donaldson, by Ferry ('13), and by Jackson. Growth graphs constructed from data obtained by the first two of these investigators and graphs from my own series of animals are given in chart 4 and in chart 5.

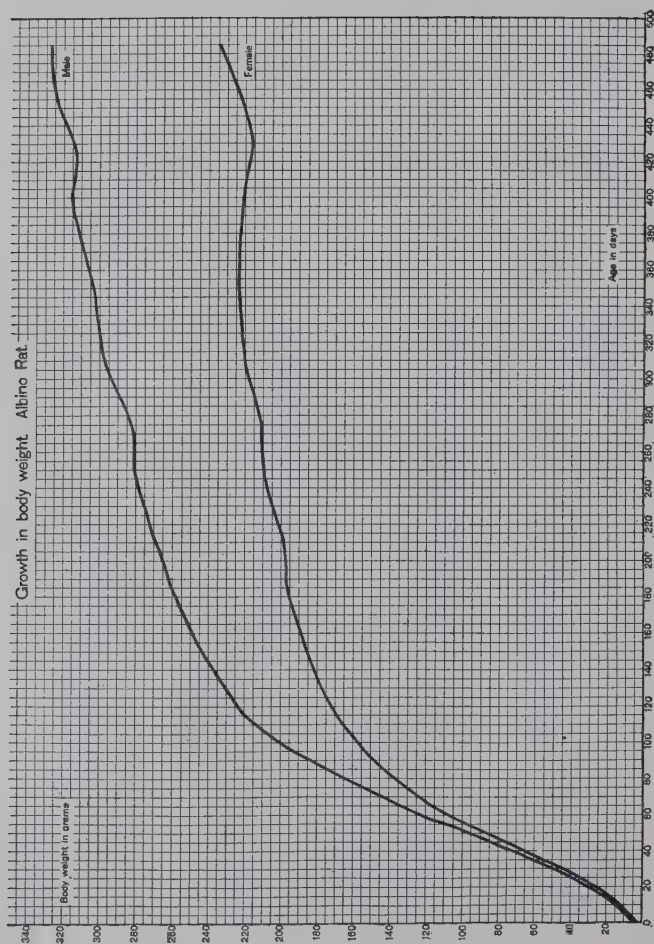


Chart 3 Graphs showing the growth in body weight of male and female stock albino rats (data in table 3).

The first data recorded for the growth of the albino rat in body weight were obtained by Donaldson from a series of animals reared in the laboratory of the University of Chicago. Bread and milk formed the staple food of the rats used in this investigation: this diet being varied occasionally by the addition of vegetables, meat, corn and sunflower seeds.

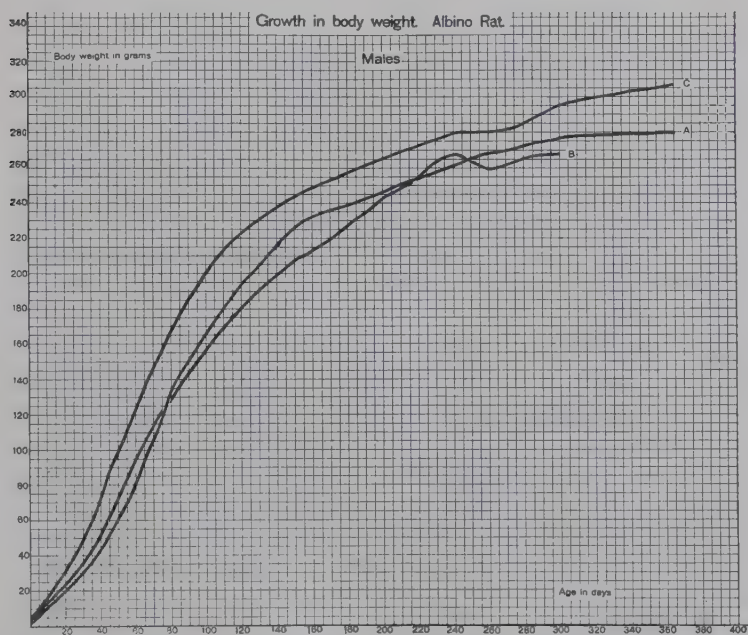


Chart 4 Graphs showing the growth in body weight of three series of male albino rats reared under different environmental conditions. A, graph constructed from data obtained by Donaldson; B, graph constructed from data furnished by Ferry; C, graph constructed from data recorded by King.

Donaldson's growth graph for the male albino rat (A, chart 4) is based on data for 19 animals weighed at varying intervals for one year. This graph has practically the same form as that for the male rats reared in The Wistar Institute colony (C, chart 4), but it runs considerably lower throughout its entire length. The space between these graphs represents, for the adult rats,

a difference of about 20 grams in the average body weight of the two series of animals.

Graph B in chart 4 was constructed from growth data for about 50 male albino rats bred in the laboratory of Yale University. These data were kindly furnished by Miss Ferry, who used them in her study of "The rate of growth of the albino rat." As regards the food given the rats Miss Ferry states in a letter: "The diet of the rats consisted of Austin's dog biscuit, sunflower seeds with fresh vegetables (chiefly carrots or corn and string beans) two or three times a week, and a small amount of cooked meat twice a week. A little salt was always kept in the cages."

The growth graph for the albino males based on Ferry's data closely follows Donaldson's graph, running a little above it in the beginning but falling below after the 60-day period. The drop in graph B at the end is due to the fact that Ferry included in her records the body weights of some adult animals that were probably ill.

The body weight of the albino rat at any given age depends to a considerable extent on the character of the food, as has been shown experimentally by Hatai ('07) and by Osborne and Mendel ('11). The fact that the male rats from which the data for Graph C were obtained grew more rapidly and attained a greater absolute weight than the rats reared by Donaldson and by Ferry can doubtless be ascribed in great part to the difference in the food that the animals received. The 'scrap' food given the rats in The Wistar Institute colony contains a relatively larger amount of meat and of fresh vegetables than the diet supplied to the rats used in the other two series of investigations noted. Considerable quantities of these substances are evidently needed by the rat to supply the materials needed to stimulate vigorous and continued growth.

Growth graphs for the body weights of the female albino rats used in these three series of investigations are given in chart 5.

The growth graphs for the three series of female rats bear very different relations to each other from those shown by the graphs for the males of the series (chart 4). The graph constructed from the data furnished by Miss Ferry (B, chart 5) is consider-

ably lower than either of the other two graphs. This indicates either that exceptionally small rats were used for her investigations, or that the animals were not in good physical condition and so did not gain in weight at a normal rate. Whether these females were allowed to breed is not stated.

As investigations made by Watson ('05) had shown that female rats that are allowed to breed are heavier than unmated females of the same age, the growth graph for female albino rats as given by Donaldson, and reproduced as graph A in chart 5,

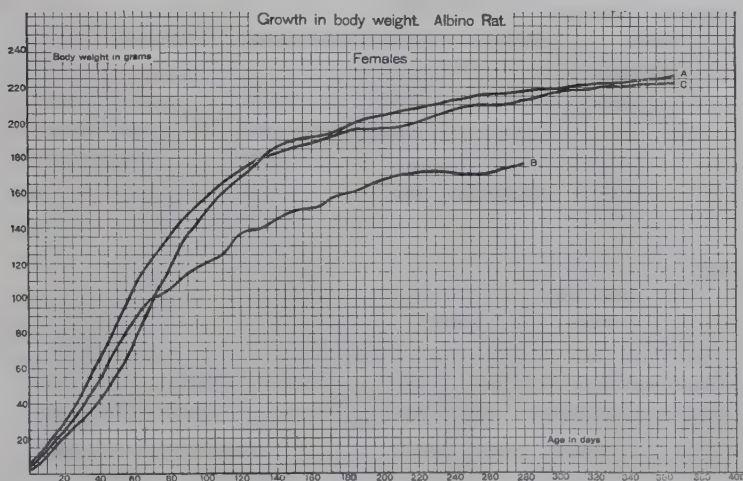


Chart 5 Graphs showing the growth in body weight of three series of female albino rats reared under different environmental conditions; lettering as in chart 4.

was constructed from the actual weight data of unmated females up to the 90-day period, and beyond this point the data used were the body weights of unmated females corrected to accord with the weights of breeding females as calculated by Watson's formula.

The female rats belonging to Donaldson's series grew very slowly at first, as is shown by the position of graph A in chart 5. At 120 days of age the average body weight of the females used in my investigations was 173 grams. This is practically the es-

timated weight for breeding females of this age as calculated by Donaldson. In chart 5, graph A meets graph C at this point and subsequently runs parallel with but slightly above it. It is, of course, impossible to obtain, at stated intervals, the true body weights of albino females that are allowed to breed. Pregnancy produces a temporary increase in weight that may amount to 50 grams or more, while the nursing of a large litter usually causes the female to lose considerable weight. To weigh females only after they have recovered from nursing a litter makes the intervals between the weighings too long to give weight records of much value. Positive errors in the weighings of females during early pregnancy undoubtedly occur in my records, but, as previously stated, such errors would be very slight, and they have probably been balanced by negative errors due to the weighing of nursing females or of females that were ill. Graph C is probably, therefore, fairly representative of the average body growth of albino females that are allowed to breed. It is of interest to note that the graph constructed from actual weight records for breeding females runs close to the theoretical graph.

In his paper on the postnatal growth of the rat, Jackson gives some data for the body weight of male and of female albino rats of various ages, but these data are not extensive enough to make it possible to construct from them growth graphs similar to those in chart 4 and in chart 5. From the records given it would appear that the rats used by Jackson were relatively small, since the males had an average weight of 213.0 grams when they were one year old, while the average weight of the females at this age was 163.7 grams: corresponding figures for the rats in my series give 306.1 grams as the average weight of the males, and 223.1 grams as the average weight of the females at one year of age.

An interesting comparison between the rate of growth of the male and of the female albino rat during the early stages of development has been made by Donaldson. His records show that as early as the seventh day after birth the female rat grows more actively than the male and is, as a rule, a relatively heavier animal up to about 55 days of age. At this point the male

shows a very rapid gain in its rate of growth and he is much heavier than the female at all subsequent ages.

Jackson found that "the excess of average weight was invariably in favor of the male at birth, and also in the majority of cases at all succeeding ages." In general, however, his data seem to confirm Donaldson's conclusion that the growth of the female is more vigorous than that of the male during the first two months of postnatal life.

In the thirteen litters of rats used in my investigations there was only one litter in which the average weight of the females at thirteen days of age exceeded that of the males. In this case the average weight of the females was 18 grams while that of the males was 17 grams. In one litter the average weight of the females at 30 days of age was exactly the same as that of the males, but in all other litters the males averaged from one to eight grams heavier than the females. At 60 days of age a few of the females weighed slightly more than the smallest males in the same litter, but in no case did any female have a weight equal to that of the largest male. In this series of animals the male tends to exceed the female in body weight in early as well as in late stages of development, but up to about 60 days of age the difference is very slight. Growth graphs for the two sexes, shown in chart 3, run very close together at first and begin to diverge only after the animals have reached 60 days of age. Female rats attain their maximum weight sooner than do the males, thus indicating that their rate of growth exceeds that of the males, although their absolute body weights may be less than those of the males at any given age. Evidence that the female rat tends to develop somewhat more rapidly than the male is also shown by the fact that, as a usual thing, the female rats in a litter open their eyes several hours sooner than do the males.

VARIABILITY IN THE BODY WEIGHT OF THE ALBINO RAT

Even with environmental and nutritive conditions as nearly uniform as possible, rats of the same sex belonging to the same litter show marked differences in body weight that must be attributed to factors inherent in the 'germplasm' from which the individuals were derived. By studying the magnitude of the

variation in these body weights we can obtain some idea as to the range in the action of these unknown intrinsic factors of growth even if we get no hint as to the nature of the factors themselves.

The relative extent of variability in body weight, as well as in other characters, is at the present time best determined through the coefficients of variation obtained for the body weights at each age at which weighings are taken. Since the frequency curves for both male and female rats when plotted from the data given in table 3 are fairly symmetrical, it was possible to obtain the coefficients of variation for the body weights according to Pearson's formula as given by Davenport ('14).

The index of variation (σ) was first obtained by the following method:

$$\sigma = \sqrt{\frac{\text{sum of [(deviation of class from mean)}^2 \times \text{frequency of class}]}{\text{number of varieties}}}$$

The coefficient of variation (C) was then found by the following formula in which the number of the varieties is indicated by the letter N.

$$C = \frac{\sigma}{N} \times 100 \text{ per cent.}$$

The coefficients of variation for this series of body weights are relatively small, being in many cases less than 10 per cent. It was possible, therefore, to calculate the probable error in these coefficients (EC) by the formula:

$$EC = 0.6745 \frac{C}{\sqrt{2N}}$$

Table 4 gives the coefficients of variation with their probable errors for the body weights of the male and of the female rats used in the two series of investigations described above. For the 13- and for the 30-day periods grouped data were used in making the calculations, as only the average body weight of the individuals of each sex was recorded in the weighings of the various litters at these ages: for all other ages the individual data were used.

The range of variability in the body weights of the male rats is practically the same for the two series of litters weighed, as the difference between corresponding coefficients of variation is not more than three in any instance (table 4). The coefficients given in table 4 for the body weights at 13 and also at 30 days are doubtless lower than would be the case had the coefficients been calculated from individual and not from average body weights. The high coefficients for the males at 60 and at 90

TABLE 4

Showing the coefficients of variation with their probable error for the body weights at different ages of the two series of stock albino rats

AGE IN DAYS	SERIES 1		SERIES 2		BOTH SERIES	
	Males	Females	Males	Females	Males	Females
13	11.2±1.11	8.3±0.82	10.2±0.93	14.9±1.36	11.8±0.79	11.4±0.76
30	10.8±1.07	12.2±1.20	9.1±0.82	8.7±0.79	10.2±0.68	11.0±0.74
60	17.3±1.61	16.1±1.59	14.3±1.30	12.9±1.18	17.0±1.14	15.7±1.05
90	15.1±1.49	12.3±1.46	14.3±1.30	12.5±1.23	14.8±0.99	12.5±0.95
120	13.6±1.34	10.1±1.16	13.1±1.20	10.3±0.97	13.4±0.90	10.3±0.75
151	14.2±1.40	9.4±1.05	12.8±1.17	11.1±1.01	13.3±0.89	10.4±0.73
182	14.7±1.45	12.6±1.27	13.7±1.25	12.5±1.29	14.2±1.22	12.3±0.90
212	14.1±1.42	13.9±1.55	13.9±1.29	10.8±1.05	14.0±0.96	12.4±0.91
243	13.8±1.42	13.7±1.49	13.9±1.37	11.3±1.09	13.9±0.99	12.6±0.91
273	13.4±1.42	12.9±1.53	12.6±1.30	10.8±1.09	13.4±0.99	11.5±0.89
304	13.8±1.55	9.9±1.11	14.4±1.60	9.1±0.96	14.0±1.11	10.3±0.79
334	13.8±1.65	8.9±1.02	13.2±1.52	10.7±1.10	13.7±1.13	10.8±0.87
365	13.2±1.81	10.2±1.23	12.7±1.52	10.8±1.28	13.0±1.16	10.7±0.91
395	13.4±2.07	10.1±1.22	12.0±1.47	11.2±1.33	12.6±1.22	11.5±0.98
425	11.8±1.98	10.5±1.44	14.1±1.45	12.2±1.36	13.4±1.32	10.9±0.94
455	11.5±2.23	7.8±1.40	14.5±2.30	9.1±1.33	13.6±1.67	8.9±0.99
485	15.5±4.28	5.6±1.90	14.6±2.32	14.4±2.28	15.0±2.06	13.4±1.77

days indicate that the maximum variability for this sex comes at this period. For the adult males the range of variability in body weight is practically constant for all the ages studied up to one year. From this point it tends to diminish slightly, as Minot ('91) found to be the case in guinea-pigs.

The high coefficients of variation for the body weights of very old males, as shown in table 4, can have little significance although they occur in both series, owing to the small number of individuals

weighed at this time and to the fact that the probable errors in the coefficients are relatively large.

Corresponding coefficients for the body weights of the female rats in the two series do not accord as well as do those for the males. There is, in fact, no agreement whatever between the coefficients for the first three ages at which the animals were weighed. In the first series the highest coefficient (16.1) is that for the females at 60 days of age; in the second series the highest coefficient (14.9) is that for the 13-day period. Coefficients for the body weights of the females of the first series at 90 and at 120 days of age are practically the same as the corresponding coefficients for the second series, and the coefficients for later stages show no significant differences. The range of variability in the body weights of the females that lived to 485 days of age is curiously unlike in the two series. Females of the first series that lived to this age varied little in their body weights, as the coefficient of variation is only 5.6; while the females of the second series exhibited a very wide range of variability in their body weight, as is indicated by a coefficient of 14.1. The relation of body size to longevity in the rat is a point that will be considered in detail when a larger series of records is available for analysis.

The coefficients of variation for body weights at different ages, calculated from the data for all of the individuals in the two series, are given in the last two columns of table 4. From these coefficients it is possible to compare the range of variability in the body weight of 50 albino males with that of 50 females. At 13 and at 30 days of age the females seem to be quite as variable in body weight as the males, as the coefficients for body weight of the sexes at these ages are much the same. Males and females show their maximum range of variability in body weight at 60 days of age, but the coefficient of variation for the body weight of the males is 17.0 against 15.7 for that of the females. The males are more variable in body weight than the females from this time on, as at every subsequent age the coefficients for the male weights are higher than those for the female weights, although when the probable errors in these co-

efficients are taken into consideration the difference in favor of the males is very slight in many cases.

Other studies on the rat also seem to show a greater variability in the males than in the females. Hatai ('08) found that in skull measurements the males show a greater tendency to variability than do the females. Jackson's data show that males are more variable than females in body weight except at 20 days of age, and he concludes that "variability in body weight is lowest at birth (the coefficient being about 12) and is not much higher at seven days (16). It appears highest at three weeks (28), and at later periods varies from 19 to 21. The average coefficient, taking all ages together, is 19." In my investigations I find that the maximum coefficient of variation for the body weight of the rat comes at 60 days in both sexes, and that the average coefficient is much smaller than that calculated by Jackson, being 13.6 for the males and 12.1 for the females. The fact that Jackson's calculations were based on data obtained from rats that represented "for the most part a random sample of the general population at each age," while mine were based on the weighings of the same series of individuals throughout the entire period of observation, undoubtedly accounts for the differences in our results.

It has been held by many investigators, among whom are Darwin ('71) and Brooks ('83); that throughout the organic world the male tends to be more variable than the female. The known facts regarding variability in man have been collected by Ellis ('11) who sums up his discussion of the subject with the following statement: "In man, as in males generally, there is an organic variational tendency to diverge from the average; in woman, as in females generally, an organic tendency * * * to stability and conservatism involving a diminished individualism and variability." Pearson ('97) attempts to refute this theory, which he states is based chiefly on the fact that pathological variations seem to occur more frequently in man than in woman. After a critical examination of a large mass of growth statistics for various races Pearson concludes that, although men are more variable than women at certain ages and in certain characters,

yet there is not a pronounced difference between the sexes as regards variability, the weight of evidence indicating slightly greater female than male variability. Data regarding variability in the rat as collected by Hatai, by Jackson and by myself do not support Pearson's contention, since these data show that, in the characters tested, there is decidedly greater variability in the male than in the female rat.

Boas ('97) and Porter ('05), among others, have shown that in man variability in body weight is correlated with rapidity of growth. A similar correlation in the rat is not shown by Jackson's data, although it seems to be indicated by my results judging from the relative size of the coefficients for body weight at various ages as given in the last two columns of table 4. Since in this table the coefficients given for the 13- and for the 30-day periods were calculated from the average body weights of groups of rats and not from individual data they cannot justly be used to give evidence on this point. At 60 days of age, when the rats are still growing very rapidly as is indicated by the growth graphs in chart 3, the coefficients of variation are higher for both males and females than at any subsequent period. The rate of growth is beginning to slacken at 90 days of age, and the coefficients indicate a corresponding lessening in the range of variability of the body weights. At 120 days of postnatal life the period of rapid growth is at an end, and it is significant that at this point the coefficients for both sexes drop to the level that is maintained, with no important change, up to one year of age, when growth has practically stopped. Correlation between the rate of growth and variability in body weight exists in the rat in a late period of adolescence according to these records, but further investigations will be necessary in order to determine whether this correlation also exists at birth and during the early stages of development.

Two of the litters of rats used for this study contained an unusually large number of individuals of the same sex: one litter was composed of nine males and three females; the other had seven females and two males. For the purpose of comparing the variability within the litter with that of the general popula-

tion as determined from the data for all of the litters weighed, growth records for these two litters are given in table 5 and in table 6. Data for the males, together with their coefficients of variation, are presented in table 5.

On comparing the data in table 5 with the corresponding data in table 3, it is found that the average body weight of these nine males greatly exceeds that for the males of the general pop-

TABLE 5

Showing the increase in body weight with age and the coefficients of variation for nine males belonging to the same litter of stock albino rats

AGE IN DAYS	BODY WEIGHT IN GRAMS			COEFFICIENTS OF VARIATION	NO. INDIVIDUALS
	Average	Lowest	Highest		
13.....	15.0				9
30.....	50.0				9
60.....	115.1	98	135	9.6 ± 1.52	9
90.....	177.7	162	206	7.9 ± 1.25	9
120.....	220.5	199	242	6.5 ± 1.03	9
151.....	246.6	231	269	5.1 ± 0.80	9
182.....	262.2	231	287	7.1 ± 1.12	9
212.....	273.0	234	298	6.8 ± 1.14	8
243.....	296.0	241	329	10.1 ± 1.69	8
273.....	311.5	252	349	9.5 ± 1.59	8
304.....	338.1	269	379	10.0 ± 1.68	8
334.....	341.5	278	385	8.6 ± 1.44	8
365.....	334.0	270	377	10.0 ± 1.68	8
395.....	336.3	273	376	9.8 ± 1.65	8
425.....	331.2	267	397	13.3 ± 2.23	8
455.....	345.6	289	414	13.7 ± 2.66	6
485.....	341.4	297	437	15.0 ± 3.19	5

ulation after the animals reach the age of 120 days. This result may be due, possibly, to the fact that the litter to which the males belonged happened to be by far the best of the 13 litters weighed, judging from the size and vigor of the individuals and from their longevity.

Growth data for the seven females belonging to the same litter with the coefficients of variation for their body weights at various ages, are given in table 6.

After the age of 60 days the average weight of these seven females exceeded that of the females representing the general population, as may be seen by comparing the corresponding data in table 6 and in table 3. The largest females in the series studied were not contained in this litter, but were members of the litter containing the nine males whose growth data are given in table 5. Whether there is any correlation between the number of individuals of the same sex in a litter and the size of the indi-

TABLE 6

Showing the increase in body weight with age and the coefficients of variation for seven females belonging to the same litter of stock albino rats

AGE IN DAYS	BODY WEIGHT IN GRAMS			COEFFICIENT OF VARIATION	NO. INDIVIDUALS
	Average	Lowest	Highest		
13.....	12.5				7
30.....	41.0				7
60.....	105.5	99	121	6.4 ± 1.15	7
90.....	164.0	143	177	9.2 ± 1.78	6
120.....	176.5	160	195	6.5 ± 1.16	7
151.....	204.2	163	220	8.9 ± 1.59	7
182.....	205.4	190	223	6.6 ± 1.40	5
212.....	215.6	197	228	4.9 ± 1.04	6
243.....	225.0	204	256	7.7 ± 1.38	7
273.....	231.4	193	254	8.5 ± 1.53	7
304.....	242.8	212	265	7.4 ± 1.32	7
334.....	240.0	215	259	6.3 ± 1.22	6
365.....	239.0	220	255	5.3 ± 1.12	5
395.....	221.6	198	243	6.5 ± 1.68	5
425.....	224.4	203	250	5.4 ± 1.15	7
455.....	220.1	198	239	6.0 ± 1.16	6
485.....	234.8	226	250	4.3 ± 0.91	5

viduals, as the records from these two litters seem to indicate, can only be determined from the data of a much larger series of litters.

The coefficients of variation for the males of one litter, as given in table 5, are considerably lower than those for the males of the general population (table 4) up to the time that the animals were 425 days old: the small number of individuals weighed at an advanced age make it impossible to draw any conclusions from

the data given. Coefficients of variation for the body weight of the seven females from the one litter are likewise considerably below those for the females of the general population (table 4). From these facts it follows that variability within the litter unit is less than that of the general population, as Jackson has already shown.

The variability in the body weights of the male members of a litter is greater than that in the female members of a litter, as is shown by comparing the coefficients of variation given in table 5 with those in table 6. The difference, as might be expected, is about the same as that between the males and females of the general population.

From an examination of the coefficients of variation for the body weights of the individuals belonging to several litters, Jackson concludes that "in general the variation in body weight within a given litter of albino rats is probably less than half that of the general population of the same age under similar environment." Taking all ages together I find that the average coefficient of variation for the body weights of the nine males from the one litter is 9.5, while that for the males of the entire series is 13.6 (table 4); for the seven females belonging to the same litter the average coefficient of variation is 6.7, that for the females of the general population being 12.1. In this instance the range of variability within the litter is about 70 per cent that of the general population in the case of the males, while for the females it is about 55 per cent. These figures seem to indicate that the relation between fraternal variability and racial variability for the body weight of the rat is much the same as that for human stature which, according to Galton ('94), is approximately 62 per cent. Definite conclusions regarding this point cannot be drawn from a consideration of the records from such a small number of litters, but must be deferred until a larger series of data is available for analysis.

SUMMARY

1. The present paper gives the data for the increase in body weight with age for two series of stock albino rats reared under similar environmental conditions. Altogether thirteen litters containing 100 individuals, 50 males and 50 females, were used in this study.

2. Growth graphs for each sex, constructed from the average body weights at various ages, are practically the same for the two series of rats used (charts 1 and 2). From this fact it follows that, when environmental conditions are uniform, the growth of albino rats within a given colony tends to follow the same course and to produce individuals having a like weight at any stated age.

3. As a rule, the male rat is heavier than the female at birth and also at all subsequent ages at which records were taken. During the first 60 days of postnatal life the body weight of the female tends to approach that of the male, but after this age the male grows more rapidly than the female and soon greatly exceeds her in body weight. At 200 days of age the male rat weighs, on the average, about 70 grams more than the female of the same age (chart 3).

4. The female rat tends to increase in body weight at a much more rapid rate than does the male during the early stages of development, and she reaches her maximum weight much earlier than does the male.

5. The environmental and nutritive conditions under which rats are reared have a marked influence on their body weights, as is indicated by the relation of the growth graphs constructed from data obtained from three different series of rats reared under different conditions (charts 4 and 5).

6. Variability in the body weight of the albino rat, as measured by the coefficients of variation, is greatest when the animals are about 60 days of age. It decreases slightly at 90 days, and

after 120 days remains practically constant until the animals are about one year old.

7. Very young female rats seem to show as great a range of variability in body weight as do the males, but the males are more variable than the females at all later stages of growth.

8. The average coefficient of variation for the body weights of the 50 male rats used in this study is 13.6; that for the females is 12.1.

9. In the rat there is apparently a direct correlation between the rapidity of growth and the variability in body weight after the animals have reached 60 days of age. The records collected are not in a form to give evidence regarding the correlation that exists at earlier stages of growth.

10. Fraternal variability in the rat is less than racial variability. For the male rat the fraternal variability is about 70 per cent that of the general population; for the female it is about 55 per cent.

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TAILLESSNESS IN THE RAT

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From the Wistar Institute of Anatomy and Biology

THREE FIGURES

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INTRODUCTION

There seems to be a general opinion that when a rat appears without a tail it means the loss of the tail by accident early in the animal's life, and it is usually suggested that it was bitten off by another rat at the time of birth or soon after. The objects of this paper are to describe skeletal conditions in the region posterior to the thoracic vertebrae of several tailless rats, and to correct the existing impression that a tailless rat occurs through the accidental loss after birth of a once existing tail. As to the word tailless; by tailless we mean here "with no caudal vertebrae." There are cases, of course, where, from disease or from some accident after birth, the tail has become simply a stub, but in these cases some caudal vertebrae remain.

HISTORICAL SURVEY

Little data seems to have been recorded concerning the tailless condition of the higher animals. Short tails have been noted among cats, fowls, and dogs, while the number of caudal vertebrae has been found to vary in some other animals, but only

among dogs have cases been recorded where the caudal vertebrae of a mammal were completely absent.

Hind ('89), Anthony ('99), Kennel ('01), and Davenport ('05) all give accounts of mating Manx cats or short-tailed cats with the long-tailed variety and having the short tail appear in many of the offspring. The ordinary cat, according to Flower ('85), has twenty-two caudal vertebrae, and according to Jayne ('98), eighteen to twenty-six. As to the number of caudal vertebrae of the short tailed cats, Flower ('85) gives three for the Manx cat, Anthony ('99) describes six, and Kennel ('01) speaks of six 'post-sacral' vertebrae in a so-called tailless cat.

Concerning fowls, Godron ('65) in a footnote says that complete lack of coccyx has been observed in a large number of fowls and that the character is very readily transmitted. He does not give any details of vertebral conditions in these cases, but, from descriptions of other 'rumpless' fowls, we conclude that the coccyx here probably was not completely lacking. In the ordinary fowl Davenport ('06) gives the number of free, caudal vertebrae as five, followed by a fused portion, the uropygial bone. Davenport ('06) describes a rumpless game female as having two unsymmetrically formed and intimately fused caudal vertebrae, followed by a knob of bone about 1 mm. in diameter, Darwin ('83) speaks of the caudal vertebrae in three rumpless fowls as being few in number and ankylosed together into a misformed mass. He also reports the inheritance of rumplessness in fowls, as does Davenport ('06).

Some other animals have been recorded as showing variation in the number of their caudal vertebrae. Bateson ('94) gives the following:

Man: (Normal number of caudal vertebrae, according to Flower, '85, three to four). A male with sacral and caudal vertebrae ankylosed together and of uncertain number; a female with the coccyx of three pieces ankylosed together.

Anthropoid apes: .

Chimpanzee: (Normal number of caudal vertebrae, according to Flower, '85, five). One animal had six caudal vertebrae and others had two to four. .

Orang-utan: (Normal number of caudal vertebrae, according to Flower, '85, four). One animal had three caudal vertebrae, three each had two caudal vertebrae, a fifth had the caudal vertebrae anchylosed with the sacral, and a sixth had only one caudal vertebrae.

Sloths: Among the sloths there was considerable variation from the normal number of caudal vertebrae.

None of the above refer to an absolutely tailless condition. We have, however, recorded by Godron ('65), a complete absence of caudal vertebrae in the dog. He examined by palpation the sacral region of a tailless female water spaniel and found at the end of the vertebral column a rounded, bony surface which he took to be the last sacral vertebra, and concluded that the coccyx was gone completely. (According to Flower, '85, the caudal vertebrae of the dog number from fifteen to twenty-three.) In his account of this female he states that, when she was mated with a tailless brother, six of the litter of seven were absolutely tailless. When she was mated with a long-tailed male water spaniel, the litter of four were all tailless like the mother. The grandfather of these dogs had a rudimentary tail 3 cm. long. Godron ('65) speaks also in a footnote of a tailless species of dog, the Dalmatian hound or brach-hound of Bourbonnais.

In all of these accounts of short-tailed and tailless animals the conditions referred to are congenital and not the result of accident.

MATERIAL AND METHODS

The material for this study was obtained from The Wistar Institute rat colony and consisted of rats of the species *Mus norvegicus albinus* and *Mus norvegicus* (pied). Specimens for the work were not abundant, since, during the past nine years, only five tailless rats have appeared in the colony, although forty thousand rats have been observed. Of these five, one was eaten by an older rat soon after birth, one male is at present mated in the colony, and the remaining three rats were killed and examined.

The method of examining these rats was as follows: The animal was chloroformed, its body weight and body length taken,

and its skin and viscera removed. The vertebral column with pelvic girdle attached was partly cleaned of its masses of muscle, covered with a boiling hot, 2 per cent solution of 'Gold Dust' washing powder (a 1 per cent solution was used for the youngest rat), and kept at about 95°C. until the flesh was softened so that it could be removed. This was done in tap water and, in addition to the usual instruments, a bone-scraper and a toothbrush were used. Care was taken not to separate the vertebrae in the region of and caudal to the pelvic girdle attachment. The bones now were dried and placed in corked vials with tar camphor balls to protect them from *Anthrenus*.

DESCRIPTION OF THE RATS EXAMINED

Of the three tailless rats whose vertebrae were examined, one was a female and two were males. The data concerning them are presented in table 1. The normal rat of this species (*Mus norvegicus*) has six lumbar vertebrae, four sacral, and twenty-nine to thirty-one caudal.

Rat No. 1, the female, was of the species *Mus norvegicus* (pied). Its parents were among some pied, pet rats of the colony. It was two years old when killed, its body weight was 171.3

TABLE 1

Data on tailless rats

RAT NO.	SPECIES	SEX	AGE DAYS	BODY WEIGHT	BODY LENGTH IN MM.	PARENTS	DATE OF KILLING
				grams			
1	<i>Mus norvegicus</i> (pied)	♀	730	171.3	193	among pied pet rats	12-14-'14
2	<i>Mus norvegicus albinus</i> ; half inbred; 11th generation	♂	388	190.9 (month earlier 210)	194	♀ × ♂ 10th stock gen. inbred	5-19-'14
3	<i>Mus norvegicus albinus</i> ; stock strain	♂	30	21.7	89		2- 8-'15

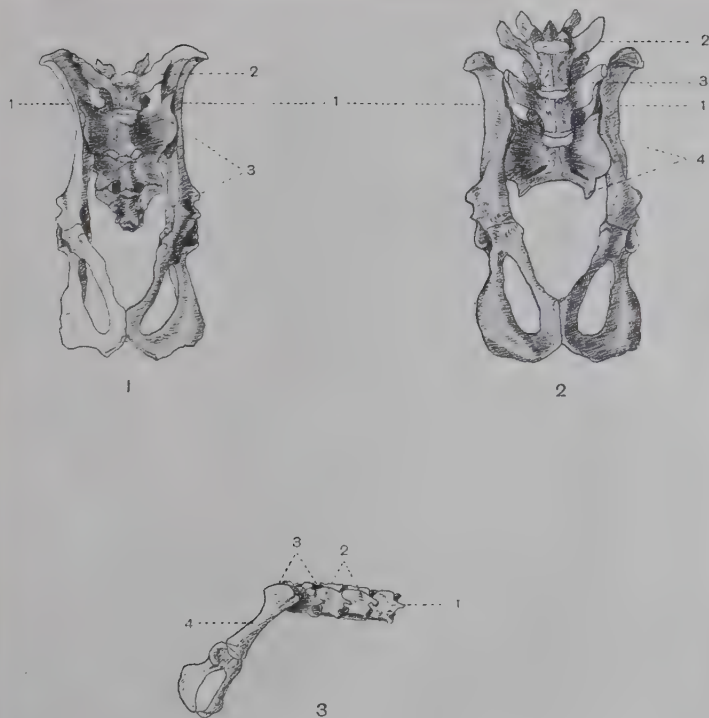


Fig. 1 Rat No. 1, ventral aspect; 1, pelvic girdle; 2, sixth lumbar vertebra; 3, three modified sacral vertebrae.

Fig. 2 Rat No. 2, ventral aspect; 1, pelvic girdle; 2, fifth lumbar vertebra; 3, sixth lumbar vertebra; 4, two modified sacral vertebrae.

Fig. 3 Rat No. 3, right lateral aspect; 1, thirteenth thoracic vertebra; 2, two first lumbar vertebrae; 3, two or three modified lumbar vertebrae; 4, pelvic girdle.

grams, and its body length was 193 mm. The arrangement of the most posterior vertebrae of this rat and their relation to the pelvic girdle may be seen in figure 1. Supposing all the lumbar vertebrae to be present, we have here, posterior to the lumbar vertebrae, only three modified sacral vertebrae. Thus one sacral vertebra and all of the caudal vertebrae are missing.

The striking feature here then is that the vertebral column ends posteriorly about midway of the long axis of the pelvic girdle, far in from the posterior end of the body.

Rat No. 2, a male, was a half-inbred albino (*Mus norvegicus albinus*) of the eleventh generation. Its mother was a strict inbred of the tenth generation and its father a stock male. When killed it was 388 days old, its body weight was 190.9 grams (one month earlier it had weighed 210 grams), and its body length was 194 mm. The arrangement of the most posterior vertebrae and their relation to the pelvic girdle may be seen in figure 2. Supposing all the lumbar vertebrae to be present, we have here, posterior to the lumbar vertebrae, only two modified sacral vertebrae. Thus two sacral vertebrae and all the caudal vertebrae are missing. Here again the vertebral column ends posteriorly far up the long axis of the pelvic girdle, even anterior to the middle of its axis.

Rat No. 3, a male, was an albino rat (*Mus norvegicus albinus*) of unknown parentage. It was thirty days old when killed, its body weight was 21.7 grams, and its body length was 89 mm. This rat was small and in rather poor condition. The arrangement of the most posterior vertebrae and their relation to the pelvic girdle may be seen in figure 3. We have here no sacral vertebrae, but two good lumbar vertebrae and two or three modified lumbar vertebrae. The last (sixth and perhaps fifth also) lumbar vertebra, all of the sacral vertebrae, and all of the caudal vertebrae are missing. In this case then the vertebral column is more modified than in the other two rats, for here the vertebrae reach only to the anterior part of the pelvic girdle, and the girdle is attached to the column merely by a small surface near its anterior end. This mode of attachment allows the posterior end of the girdle to hang very low down, almost at right angles to the column. In the living rat the sagging of the girdle was very noticeable, as it allowed the head of the femur to drop far down and thus gave an odd appearance to the posterior part of the rat's body.

This completes the description of the three tailless rats whose bones have been examined. As to the tailless male albino rat

which has been mentioned as at present mated in the colony, we are confident from inspection that in this animal also the vertebral column ends far forward along the long axis of the pelvic girdle, for this condition may be felt distinctly by pressing the finger on the rat's back in the pelvic girdle region.

The vertebral structure of all the tailless rats which we have examined seems to show that the deformity is not due to an accident after birth, since in each case the column ends in the pelvic region far from the posterior end of the body. We conclude, therefore, that the rats were born tailless, and even more than tailless, since they lack more than the caudal vertebrae.

SUMMARY

An examination of the vertebrae of three tailless rats showed that all of them lacked all of the caudal vertebrae; and besides, the first lacked one sacral vertebra; the second, two sacral vertebrae; and the third lacked one (and perhaps two) lumbar vertebra and all four of the sacral vertebrae.

In each case the vertebral column terminated in the pelvic region far anterior to the posterior end of the body, showing that the tailless condition was due not to accident after birth but to a congenital deformity of the vertebral column.

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AN ANOMALOUS ORIGIN OF THE SUBCLAVIAN ARTERY

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THREE FIGURES

The subject containing this variation is that of a large Caucasian female, aged probably 40 or 45 years, with a good muscular development and no signs of emaciation. The right subclavian arises from the aortic arch distal to the left subclavian, and the right common carotid comes directly from the aortic arch in the position usually occupied by the anonyma, which is absent in this case. Hence, instead of arising from the anonyma, the a. subclavia dextra arose directly from the aortic arch, at a point 1 cm. distal to the origin of the normal a. subclavia sinistra. From here it took a course toward the right and cephalad, across the ventral surface of the second thoracic vertebra passing dorsal to the esophagus and trachea, and making an angle of about forty degrees with the latter. Its branches are (1) an a. vertebralis dextra which arises 4 cm. from the origin of the right subclavian; (2) an a. cervicalis profunda, arising from the dorsal aspect of the subclavian 7 mm. lateral to the vertebral; (3) an a. cervicalis ascendens coming from its cranial margin 12 mm. distal to the vertebral; (4) an a. mammaria interna, from the caudal border directly below the ascending cervical; and (5) an a. transversalis colli, in the normal position, 18 mm. distal to the vertebral. After passing dorsal to the m. scalenus anterior the anomalous vessel follows a normal course into the axilla. The truncus thyreo-cervicalus, the a. thyroideus inferior, and the truncus costocervicalis were absent.

The a. subclavia sinistra arose in the usual place, but presented abnormalities in its branches similar to those on the right side. There are no truncus thyrocervicalis, an a. thyrocervicalis

inferior, or a truncus costocervicalis. The following rami arise in this region: (1) the a. vertebralis sinistra; (2) a small a. intercostalis suprema; (3) an a. cervicalis ascendens; (4) an a. mammaria interna; (5) an a. cervicalis profunda; and (6) an a. transversalis colli.

The aa. thyreoidea inferiores were absent and the a. thyreoidea ima was also missing. However, the a. thyreoidea superior on the right side was unusually large and divided into two branches as high as the level of the hyoid bone.

The right lobe of the thyroid gland was also much larger than the left and was formed by two partly distinct lobes. It is possible, but unlikely, that the upper of these two dextral lobes represents the pyramidal process, which in this case has been developed as an extra dextral lobe. A well-developed levator glandulae thyreoidea was present, connecting the capsule of the gland to the hyoid bone.

The a. carotis communis dextra is longer than usual for it also takes the place of the anonyma. As shown in figures 1 2, it follows the normal course of these two arteries, passing anteriorly and to the right as far as the right margin of the trachea and then turns almost vertically cephalad. As there is no a. thyreoidea ima, the only vessel given off below the a. thyreoidea superior is a small branch arising 13 mm. superior to the aortic arch on the ventral surface. This supplies the pericardium and the remnants of the thymus.

The n. recurrens laryngis forms a short loop above the subclavian and does not hook around it, as is usually the case. As is well known, the nn. recurrentes hook about the fourth aortic arches and as these develop into the anonyma and subclavian on the right side, and the aortic arch on the left, the nerves are dragged down to a lower level, thus establishing the recurrent condition. The fact that the right recurrent nerve does not hook around the subclavian artery may indicate that the latter was not developed from the fourth arch. An interesting recent article on the embryological development of such variations may be found in connection with a report of a similar anomaly by Cobey ('14).

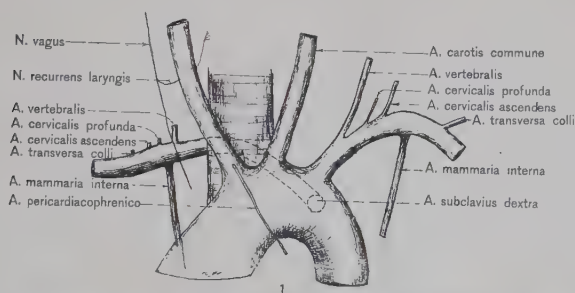


Fig. 1 Diagrammatic sketch of the actual arrangement.

Fig. 2 Trachea and esophagus pulled forward, heart and aortic arch thrown toward the left; 1, transverse portion of the aortic arch; 2, descending aorta; 3, trachea and esophagus; 4, a. carotis communis dextra; 5, a. carotis communis sinistra; 6, a. subclavius sinistra; 7, a. subclavius dextra; 8, a. mammaria interna dextra; 9, v. azygos (retracted); 10, v. cava superior.

There was no noticeable aortic impression on the vertebral column, but the anomalous subclavian (which arose from the aortic arch pointing directly toward the vertebral column and which then turned to the right at an angle of nearly ninety degrees to cross the body of the second thoracic vertebra) produced a distinct groove on the left and also a flattening across the ventral aspect of the body of that vertebra. However, if the current in the artery was impeded because of its position and origin the obstruction was not sufficient to affect the development of the right arm, for both arms seemed equally well-developed

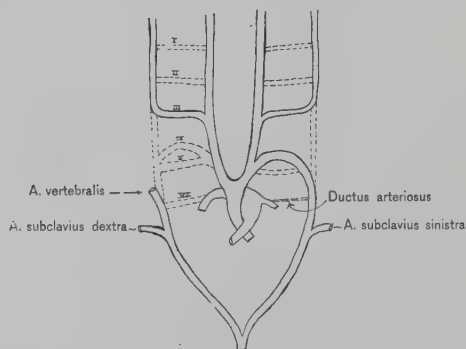


Fig. 3 Diagram indicating possible development of this anomaly (modified from Piersol).

and were covered with a good panniculus adiposus. Strangely enough, the right ulna was 1 cm., and the right radius 0.9 cm. longer than the corresponding bones of the left arm although the humeri were the same length. Although the arteria volaris superficialis originated abnormally from the radial artery about midway between the origin of the radial and the wrist no other vascular anomalies were present in the arm. The mm. palmares longi and extensores carpi ulnaris were completely absent.

The veins also exhibited slight abnormalities in the region under discussion. The vena azygos was unusually large, having a diameter of nearly 1 cm. where it joined the aorta. The v. hemiazygos crossed the vertebral column at the level of the

8th and the v. hemiazygos accessorius at the level of the 6th thoracic vertebra. It anastomosed with the v. intercostalis suprema, which joined the v. anonyma sinistra dorsal to the internal mammary and together they drained the first seven intercostal spaces.

The accompanying diagram (fig. 3), modified from Piersol, indicates the probable developmental explanation of this anomaly.

In conclusion, I wish to express my thanks to Professor Meyer for his assistance in the preparation of these notes.

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APPLICATION OF THE CAJAL METHOD TO TISSUE PREVIOUSLY SECTIONED

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While engaged in a study of the mammalian brain-stem it became necessary for me to prepare serial sections of certain regions by the Cajal method. In order to obtain a series of a large portion of the brain-stem, and in order to stain any individual section by the method of Nissl instead of that of Cajal, the problem was presented of applying the Cajal method to mounted sections. Since the Cajal method can be applied to tissue fixed in strong alcohol (the best fixative also in case of the Nissl method) the problem appeared to resolve itself into the establishment of certain conditions, mechanical rather than chemical, which would insure a uniform and sharp reduction of the silver in the cell-bodies and cell processes. Not only has this expectation proved justified but it has been possible to obtain satisfactory Cajal preparations from sections previously stained by the Nissl method; the value of applying the Nissl and Cajal methods successively to the same section needs no comment. My problem involves the demonstration of all portions of the neurones rather than that of the internal structure of the cell-body, and although the internal structure of many cells is well shown I have made no effort to adapt conditions to obtain this end. Of course the method should be varied according to the animal, region of the nervous system, or the especial picture desired. I shall now describe a method which fulfilled the requirements of my problem, namely, the correlation of the internal structure of the cell body (Nissl) with the connections of the cell processes (Cajal).

I shall assume that the tissue to be prepared is an adult human brain-stem. The entire brain-stem is placed in two liters of 95 per cent alcohol and kept in the ice-box, but the tissue should not freeze. After two hours change alcohol and leave in cold overnight; thereafter the alcohol should be changed once every day. After two or three days the tissue should be cut into pieces 1 cm. in thickness, and should remain in 95 per cent alcohol two or three days longer (always at low temperature). Dehydrate several days in absolute alcohol; clear in chloroform of good quality for two days or longer, changing twice. The pieces of tissue are then placed in a mixture of equal parts of chloroform (fresh) and 42° paraffin at 35°C. for at least twelve hours and at 50°C. for four hours. To remove chloroform place in 42° paraffin at 50° C. for at least twelve hours (four to six changes). Embed in 50 to 55° paraffin. The essentials of this technique, which is the best

one for the Nissl method also, are the avoidance of acid, quick and thorough removal of water (keeping tissue in the cold until dehydrated) and thorough impregnation with paraffin. Prolonged stay in alcohol and prolonged heating are necessary, and poor results are due not to these causes but, on the contrary, to maceration in weak alcohol and to incomplete dehydration and impregnation.

The sections are then cut; for the purpose of following the course of cell-processes $24\ \mu$ is not too thick. The sections to be prepared by the Cajal method are mounted on large slides (2×3 inches), while every sixth and every seventh section is mounted on a separate slide (one section on each slide) to be stained by the Nissl method. Of the two Nissl preparations one is retained permanently, while the other, after being studied and drawn, is restrained by the Cajal method. Mounting the sections demands certain precautions: The slides are covered with a thin film of fresh egg albumen, without glycerine or preservative, flooded with distilled water, and the albumen uniformly distributed by rubbing with a brush. The slides are then placed on a warm bar or water bath and the sections allowed to flatten out. Drain off excess of water and after the slide begins to cool (about ten seconds) express the water from beneath each section by means of a small brush. The brush must be moist but not wet, and must be rotated so that it passes over the section as a roller. The direction of the movement is indicated by the nature of the section; in the case of large sections it is often necessary to begin at the center of each section and work outward radially. The water pressed out must be removed from the slide. If the sections are not too warm and if the brush passes over the sections as a roller, a fair amount of pressure may be employed; but at first the pressure should be light and increased after most of the water has been expelled. I recommend this method for mounting large paraffin sections of the brain (especially if the sections be rather thick), and have never observed any bad results. The sections dry rapidly. The essentials in mounting are to obtain a uniform mixture of distilled water and fresh egg albumen, and to express all water from beneath the sections by rolling them with a brush. The brush should be about 4 mm. in diameter and about 1 cm. long.

When the sections are dry the paraffin is cautiously melted on a hot bar and the slides placed successively in xylol, absolute alcohol and 95 per cent alcohol; in any of these reagents the slides may remain for days without injury (this applies also to the Nissl method), but they must not be placed, even for a short time, in weak alcohol or water, and of course all traces of acid must be avoided. From 95 per cent alcohol the slides are placed (separated by intervals of at least five minutes) in a 1.5 per cent solution of silver nitrate in distilled water; this solution is kept at 55 to 60°C . A beaker holding 100 to 150 cc. is satisfactory, and this amount of solution will serve for about eight 2×3 inch slides; if used too long the solution becomes discolored and after reduction the slides show a diffuse reduction of the silver and poor contrast. In the silver bath the slides remain 10 to 15 minutes.

The most important step in the technique is the reduction. This is accomplished by a 1.5 per cent solution of pyrogallie acid in distilled water to which is added 5 per cent of formalin. This solution should be made up fresh, and should not be kept longer than two hours. The sublimed pyrogallie acid should be used, and I cannot recommend the crystalline form, which remains colorless in solution. Into a dish 8 cm. in diameter enough of the reducing solution is poured to make a depth of about 1 cm.; this solution must be renewed for each slide (2×3 inch). Before placing the slide into the reducing solution three conditions must be observed, namely, the excess of silver solution must be drained off, the hot (55 to $60^{\circ}\text{C}.$) sections must not be allowed to dry, and finally, the silver solution must be uniformly distributed over the slide (or at least over the sections and in their immediate neighborhood). To avoid drying one may pour some cool silver solution on the slide and allow slide to cool before draining off excess. A uniform distribution of the silver solution may be obtained by tilting the slide; with the aid of a bit of filter paper isolated drops may be removed or distributed. Remove excess of silver also from under surface of slide. As soon as this is accomplished the slide is quickly placed, in a horizontal position and with the sections on the upper surface, in the reducing solution. The slide is left in the reducing solution absolutely undisturbed for about $1\frac{1}{4}$ minute. The slide must undergo once more the silvering and reducing processes, and to accomplish this successfully proceed as follows: As soon as slide has remained the proper time in the reducing solution remove and flood it two or three times with distilled water; the object of this procedure is to remove some, but not all, of the pyrogallie acid. The slide is then placed on a hot bar or water bath at about $60^{\circ}\text{C}.$ and flooded with a 1.5 per cent solution of silver nitrate (not previously used) and allowed to remain one to two minutes; during this process the sections usually become darker. If under the microscope the reduction appears sufficient the slide should be very quickly washed with distilled water (two seconds) before reducing (but in the great majority of cases the slide should not be washed before the second reduction); if the first reduction appears unusually successful the second silver bath should be employed half strength, followed by reduction without previous washing. After second silver bath flood slide with cold silver nitrate solution to avoid any local concentration, due to evaporation, drain off excess, distribute evenly and reduce $1\frac{1}{4}$ minute as before; usually the same solution may be used for both reductions, but should then be thrown away. The sections are washed for a few minutes or longer in several changes of distilled water (or tap water), placed in 95 per cent alcohol, absolute, xylol, and mounted under cover in balsam. Sections may remain for hours in water, alcohol or xylol.

The principal defects to be guarded against are insufficient deposit of silver, unequal deposit of silver over slide (due to unequal distribution of silver solution before reduction), and most troublesome of all, diffuse deposit of silver (often in a finely granular state) which seriously injures the contrast. This last difficulty is due either to the deterioration of

the first silver bath (replace with fresh), to the deterioration of the reducing solution (not good for more than two hours), or to the presence of too much reducing solution in the sections when they undergo the second silvering (wash out somewhat more of the reducing solution before placing in silver bath). A third silvering and reduction is usually not desirable. Sections not too heavily stained may be counterstained with toluidin-blue as follows: Stain in a 1 percent aqueous solution of toluidin-blue (Grübler) for two hours or longer (or for a few minutes if heat be employed), wash quickly in several jars of 95 per cent alcohol, absolute, xylol, mount; the stain washes out in alcohol more readily than in the case of a primary toluidin-blue stain.

To restrain toluidin-blue sections by the Cajal method: Dissolve off cover, and thoroughly remove balsam in xylol followed by absolute. The sections are then washed in 95 per cent alcohol until as much of the toluidin-blue as possible has been removed; it is well to leave the sections in 95 per cent alcohol overnight. When the slides are placed in the silver solution the rest of the toluidin-blue comes out rapidly upon agitating the slide, but an excess of toluidin-blue causes the formation of a coarse precipitate. Accordingly, after washing the slides one or two minutes in hot silver nitrate solution they should be placed in a clean silver bath. Thereafter, the technique is the same as for unstained sections, except that the silver bath deteriorates more quickly.

I recommend this modification of the Cajal method for the human central nervous system, where I have employed it with success both on unstained material and on material previously stained with toluidin-blue. It has been used with success also on the brain of the lemur. In case of the rat's brain it failed, but just as poor results were obtained by silvering and reducing *en bloc*. The advantages of the method are: the possibility of obtaining a series of a large piece of tissue with uniform stain from center to periphery of section, the possibility of staining any section of the series by either the Cajal or Nissl method, and the conversion of a Nissl into a Cajal preparation. It is especially to be recommended when the tissue is very valuable or when the pieces of tissue are so large as to involve much labor in their preparation, since the partial failure in the case of one slide does not prevent the successful preparation of the rest. Finally, this method has an important advantage over other methods which demonstrate neurofibrils in previously sectioned material, since with the use of only a few simple reagents a paraffin section may be completed and in balsam within twenty to thirty minutes.

Below is a summary of the method, but I wish to emphasize the necessity of strict adherence to the details previously described.

1. Thorough fixation in cold in 95 per cent alcohol. After several days cut into pieces 1 cm. thick and leave in alcohol several days longer.

2. Thoroughly dehydrate in absolute (in cold).

3. Chloroform about two days.

4. Thorough impregnation with paraffin.